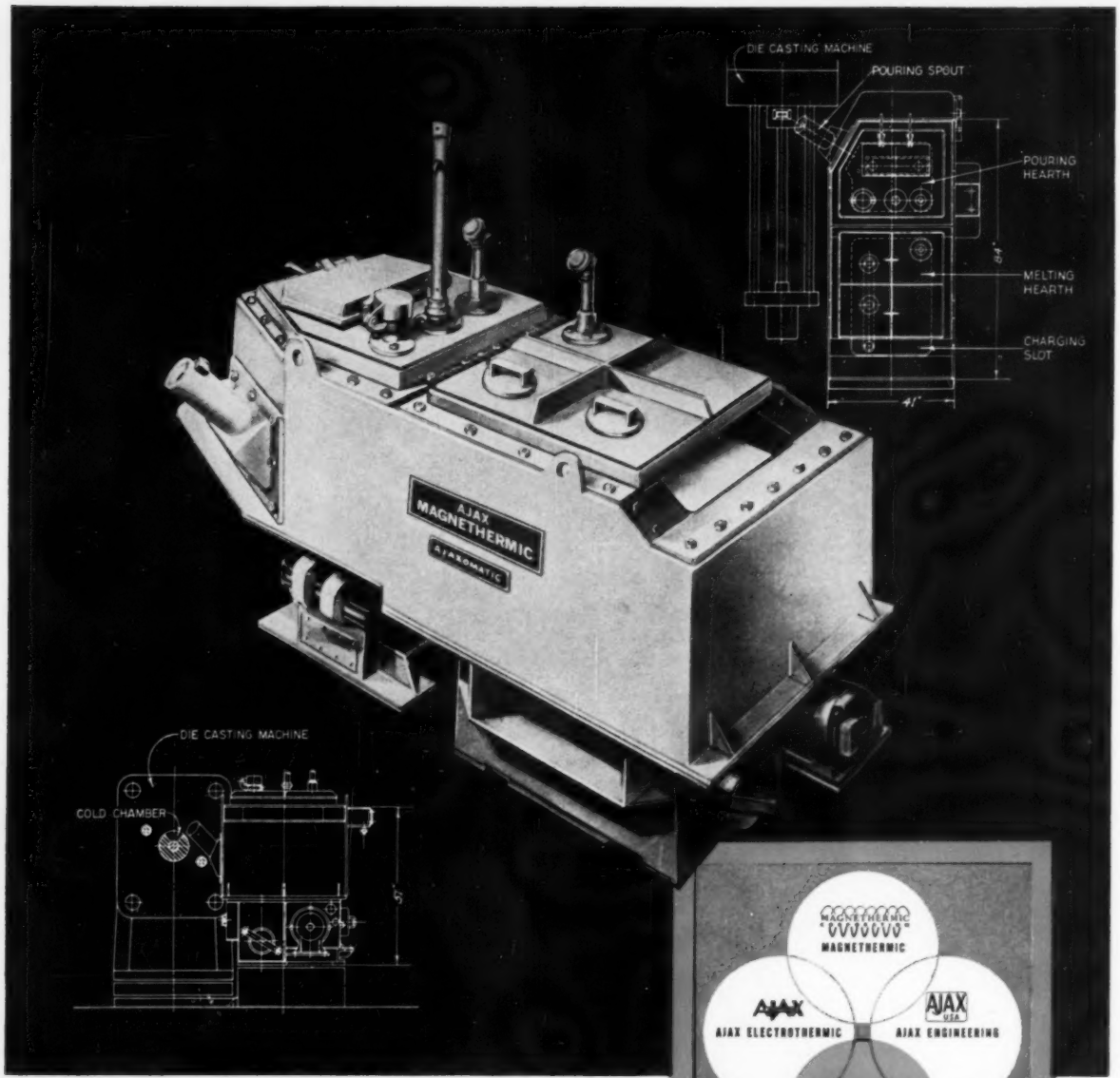
Metal Progress

July 1960



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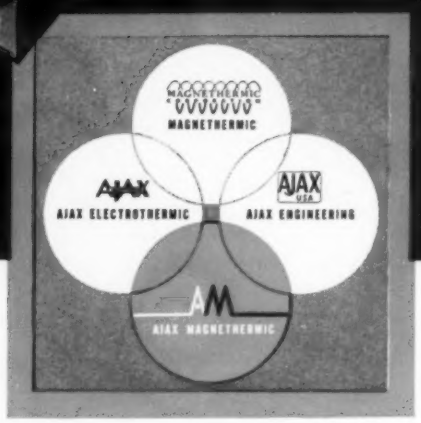

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Metal Progress

July 1960 . . . Volume 78, No. 1

Cover: Welding arc on 17-7 PH stainless steel (courtesy Boeing Airplane Co.) is described in article on p. 84. Photo on p. 83 shows welding of a large heat exchanger tube bundle at Alco Products, Inc. Montage of automobile front ends on p. 69 was provided by New Jersey Zinc Co.

Technical News in Brief

Refractory Metals Fabricated in Argon-Filled Room . . . More Parts From Stainless Steel Powders . . . Steel Industry Consumes More Oxygen . . . Burnt Lime and Oxygen Increase Steel Output . . . Lubrication With Ice . . . New Alloy for Metal-to-Ceramic Seals . . . A Better Way to Weld HY-80? . . . Material Progress in Ceramics . . . Tests Reveal Fracture Properties. 65

Metal Progress Special Report — Frontiers of Welding Progress

A Fundamental Study of the Tungsten Arc, by E. F. Gibbs 84

Through a review of theory and a photographic study of tungsten arcs under various conditions, the basic relationships between tungsten electrode configuration and flame shape and voltage and current characteristics of an arc can be determined. Much of this fundamental knowledge can be applied to practical welding. (K1; W)*

Electrodes for Welding Type 347 Stainless, by Thomas J. Moore 93

A ten-year study of techniques for welding columbium-stabilized 18-8 stainless has derived information whereby a correct choice may be made from among five electrode compositions depending on the temperature, surroundings and other conditions of service. Certain heat treatments are to be avoided since they promote rapid corrosion even of these "stabilized" compositions. (W29h, K9r, Q27, R-general, 2-60, 2-62; SS)

Problems in Field Welding Chromium-Molybdenum Pipe, by R. L. Skaggs 101

When welding these air hardening steels in the field, proper preheating and postheating, particularly the latter, are very important. Torches or ring burners are generally used. Among other items, this article also describes the use of preformed thermite assemblies for stress-relieving these welds in the field. (K9p, K9q, J1a; ST, 4-60)

Welding Solid-Fuel Rocket Motor Cases, by P. J. Rieppel 105

Hot cracking of weld metals and notch sensitivity of high-strength steels at maximum strength levels pose serious challenges to fabricators of rocket motor cases. Most failures stem from poor welding techniques and inadequate inspection. Some of the recommended practices to combat these problems are discussed. (K1, AY, SS, SGB-a)

Instrumentation for Better Welds, by D. J. Logan and W. K. Moen 111

Use of a multichannel recorder to chart the various functions in a mechanized fusion operation results in better weld quality, equipment maintenance and precise quality control. Upper control and lower control limits have been established for in-process control of each recorder parameter involved for each weld joint schedule. (S18, W29c)

Data Sheet

Weld Defects in Austenitic Stainless; Cause and Cure 100-B

Diagrams contrast various types of defects with an ideal nugget produced in spot and seam welding. (Courtesy Allegheny-Ludlum Steel Corp.)

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**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

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Metal Progress

Frontiers of Welding Progress (Cont.)

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Dip Transfer Process: Low Spatter Welding in Any Position, by A. Lesnewich 115

Welding Aluminum, Copper and Stainless Steel With Ultrasonics, by J. Byron Jones 117

High-Frequency Resistance Welding Fills Need for Fast Joining Method, by Wallace C. Rudd 120

Percussion Welding Makes Quick, Low-Cost Wire Connections, by J. S. Gellatly, K. F. Johnson and A. L. Quinlan 122

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Forge Welding High-Strength Aluminum and Magnesium Alloys, by L. A. Cook and D. G. Shafer

Electron Beam Welding: Emphasis on Precision and Freedom From Contamination, by Marsbed Hablanian 127

Button Welding – a Low-Cost Production Tool, by J. J. Chyle 129

Automatic Tube Welding Increases Reliability, Lowers Reject Rate, by L. H. Hawthorne 131

Engineering Articles

New Routes to Better Electroplate for Zinc Die Castings, by W. H. Safranek 69

In answer to demands for better corrosion protection for zinc die castings, electroplaters have come up with three promising plating practices . . . duplex nickel, crack-free chromium and duplex chromium. Already in commercial use, these coatings provide long life to decorative and functional parts, particularly in automotive applications where corrosion is a severe problem. (L17; Zn, *Ni*, *Cr*, 5-61)

Columbium Alloys Today—Considerations in Design and Fabrication of Structures, by L. P. Jahnke, R. G. Frank and T. K. Redden 76

Work is progressing rapidly to develop data needed on properties of columbium alloys for elevated-temperature applications. Tests show weldability to be excellent and coating systems indicate reliability. (Q-general, P-general; Cb-b, 17-51)

A New Fracture Test for Alloy Steels, by D. L. Newhouse and B. M. Wundt 81

Notched-bar fracture tests, such as the Charpy V-notch impact test, can be modified to simulate important characteristics of large spin bursting tests. Fracture toughness and appearances similar to those of large notched disks were obtained from specimens which were nitrided to produce a hard brittle case. (Q26r, Q6; ST, 4-51)

Correspondence

The Earliest Days of Precipitation Hardening; Comments by W. J. Kroll, W. A. Mudge, and John S. Shell 134

High-Temperature Brazing, by Karl M. Weigert; Reply by R. R. Ruppender 140

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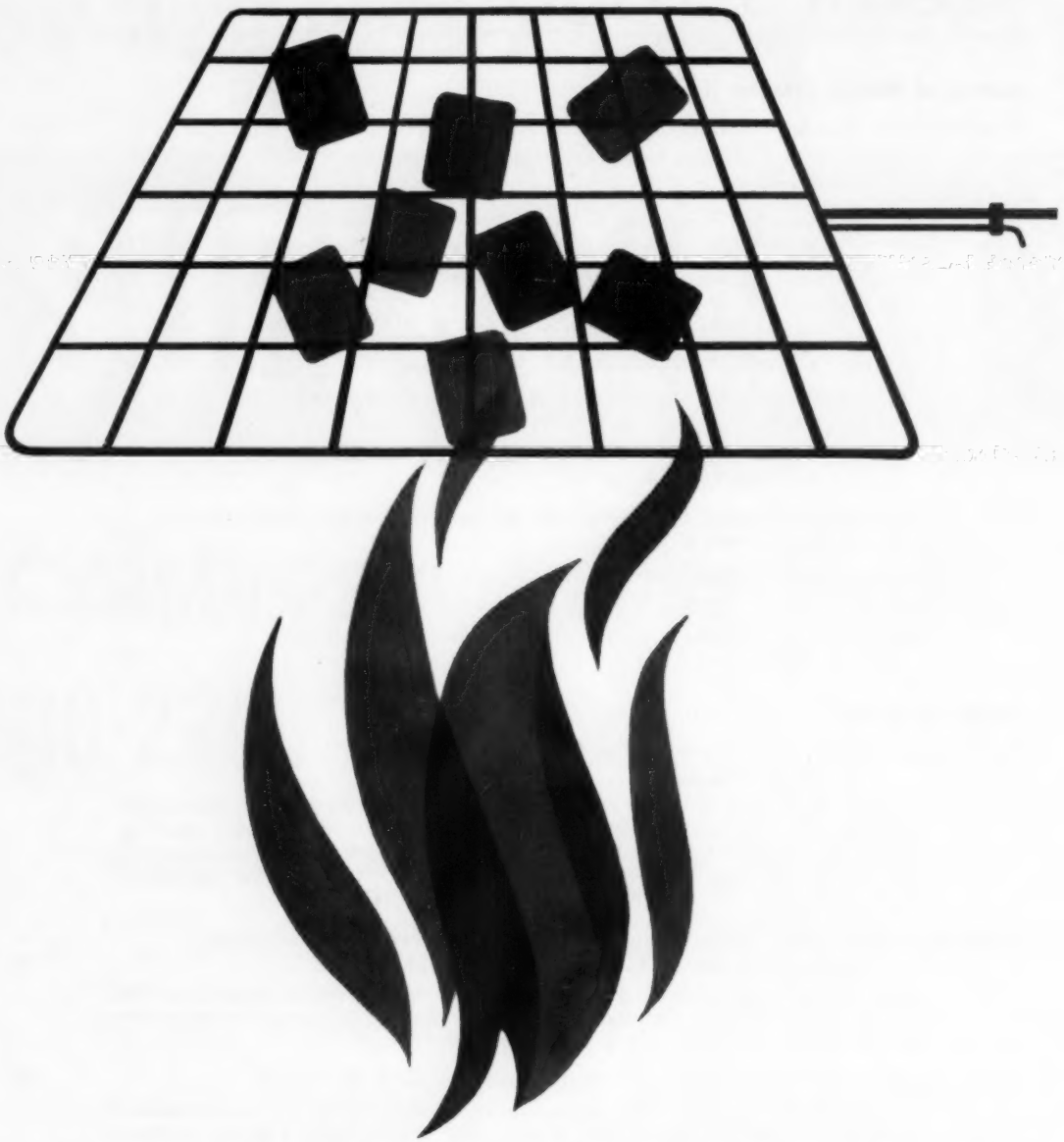

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IT HAS BEEN NOTED BEFORE in "Press Breaks" that an engineering magazine cannot hope to be all things to all men; the best it can do is to excel in its own field of technology. Consequently the editors of *Metal Progress* have avoided interesting sidelines, no matter how important. To the accusation that engineers avoid discussions of politics because they are primarily interested in their salary checks, we can reply that the members of the American Society for Metals are in all probability fairly equally divided among Republicans and Democrats, and no matter which side were upheld half our readers would raise their eyebrows.

One exception has been made, namely, periodical insertion of a page on "The Atomic Age", wherein are reprinted without comment extracts from official documents concerning the impact of nuclear energy on the world's economic and political life. The Editor-in-Chief is also now going to make another exception in reprinting a number of authoritative statements of Russian policy contained in an article entitled "Truce of the Bear", by Reginald Hargreaves, an English army officer and historian, in *Ordnance*, May-June 1960, p. 880.

Karl Marx openly averred that before Communism could triumph the British empire and the United States republic would have to be destroyed.

Lenin: "So long as capitalism and socialism exist, we cannot live in peace. We are left, therefore, with the prospect of a state of coexistence which means the absence of both peace and war in the full sense of both words, which may last for years and perhaps generations to come."

In 1938 Stalin, in his Communist decalogue, "Leninism", affirmed: "We are living, not merely in a state, but in a system of states, and it is inconceivable that the Soviet republic should continue to exist interminably side by side with imperialist states. Ultimately, one or the other must conquer. Pending this development, a number of terrible clashes between the Soviet republic and the bourgeois states must inevitably occur."

In 1945 the slogan of the Kremlin was: "The war on Fascism ends; the war on Capitalism begins."

In "Problems of Leninism" written in 1947 by Stalin we find: "The tasks of the Party in foreign policy are first to utilize every contradiction and conflict amongst the surrounding capitalist governments for the purpose of disintegrating imperialism; second, to spare no means to assist the national-liberal movement in the East; third, to spare no means to assist the proletarian movement in the West; and last to strengthen the Red Army."

To define the words "spare no means" in the above quotation, Major Hargreaves quotes a broadcast from Moscow in 1955 (and the Red radio gives out nothing but official views):

"We abide by the Leninist precept that in negotiation with the West we are justified in resorting to every kind of trick, cunning, illegal experiment, concealment and suppression of the truth. Anything is ethical and moral which promotes the building of a Communist society."

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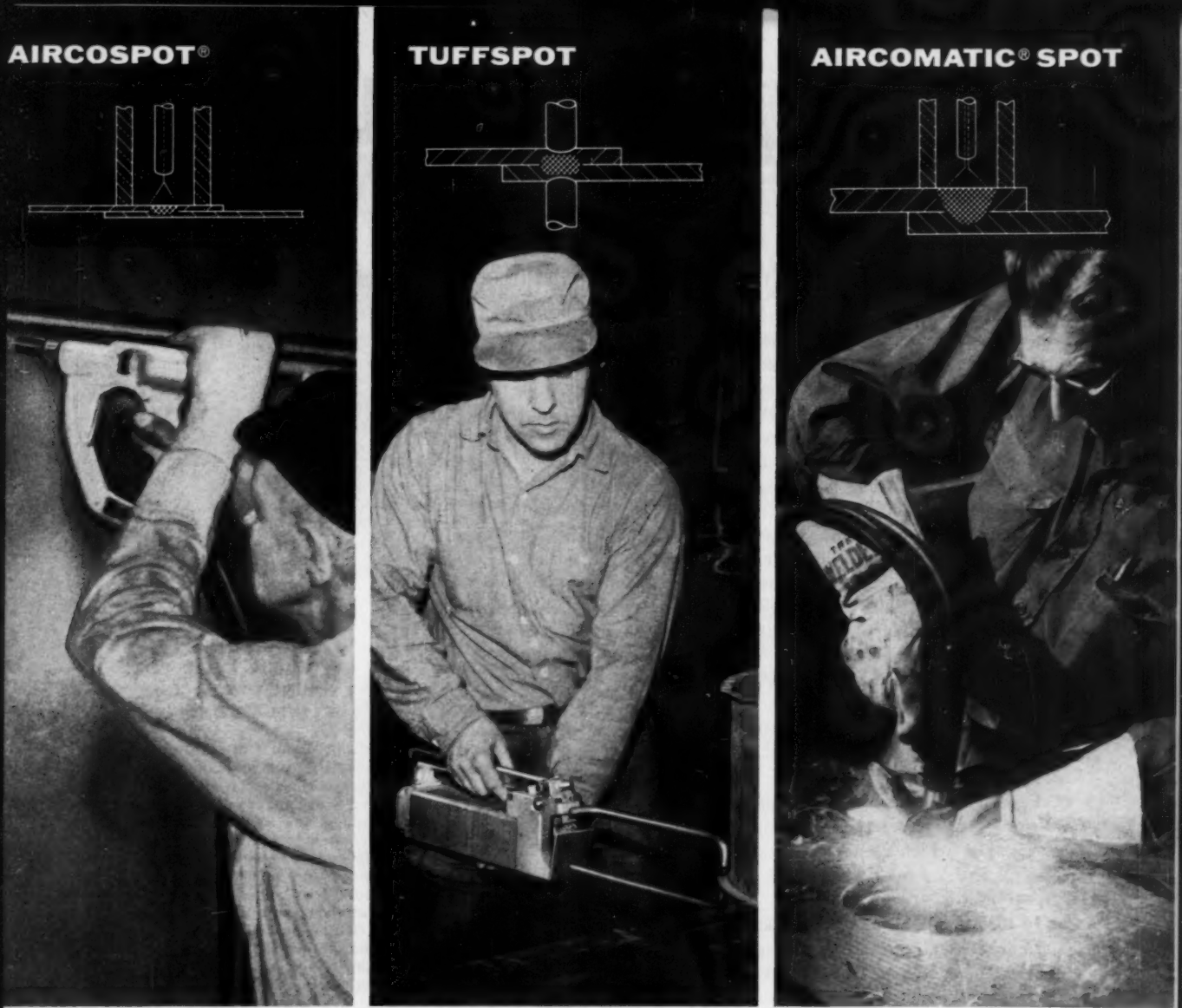

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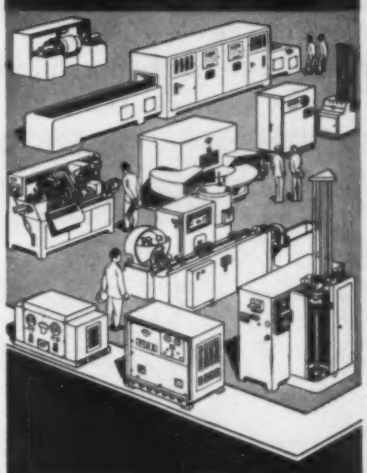

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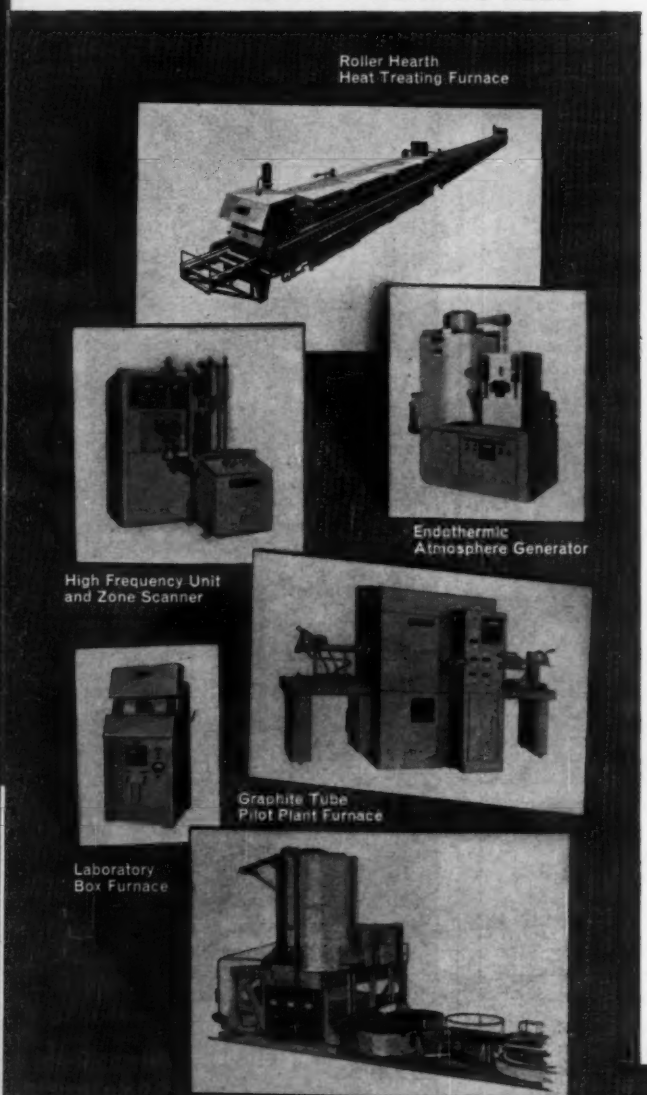

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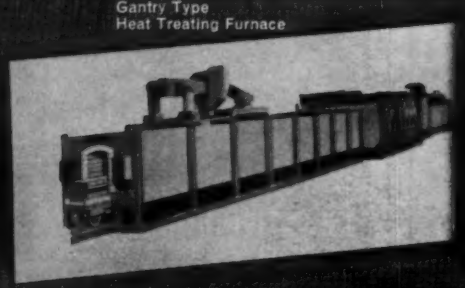
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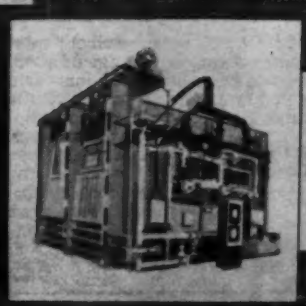
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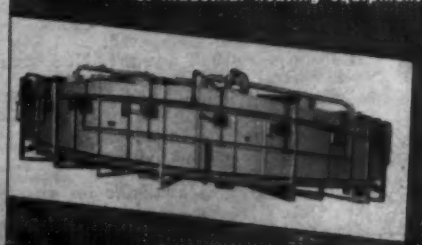
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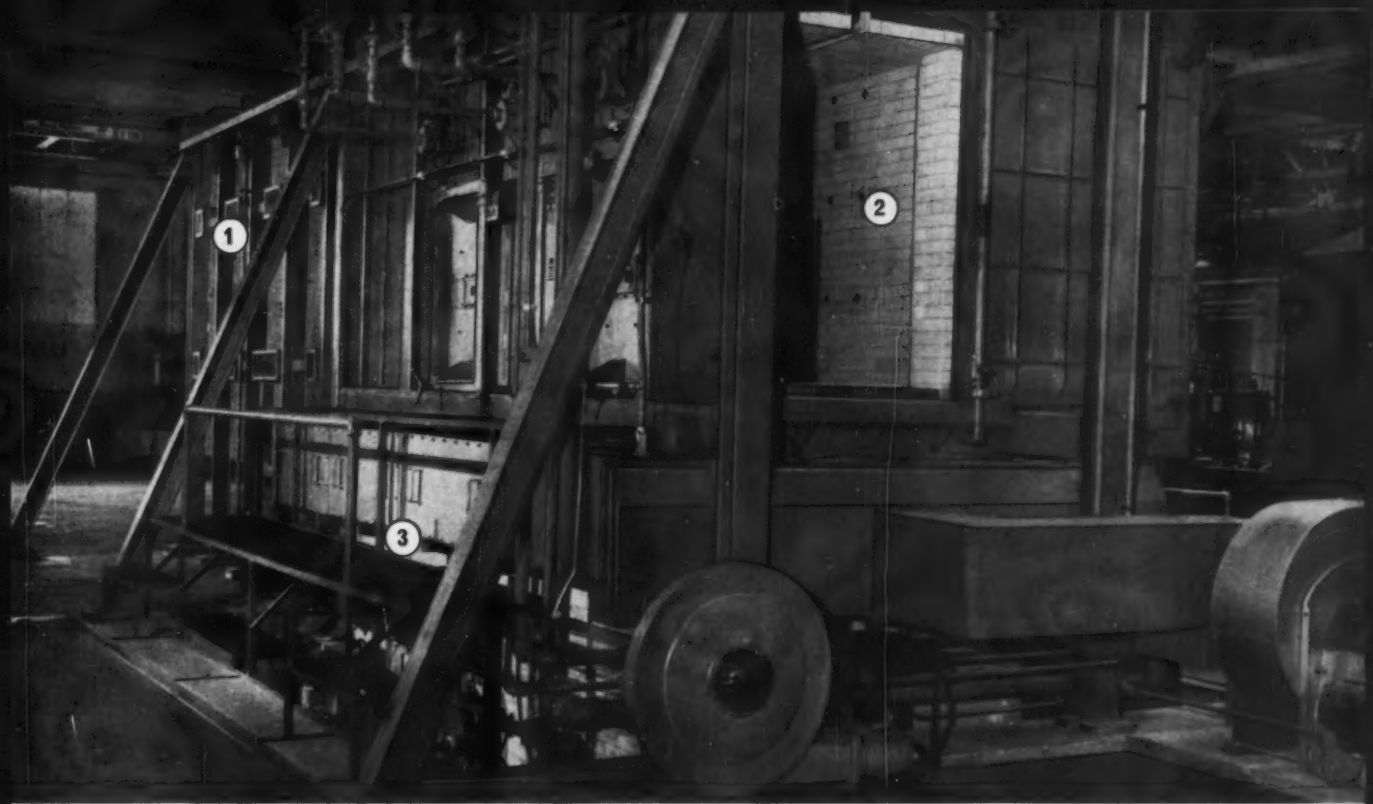

This Lindberg installation at Stewart-Warner Corporation, Indianapolis, combines (1) Pre-heat Furnace (2) Holding Furnace and (3) Lindberg-Upton Salt Bath Furnace.

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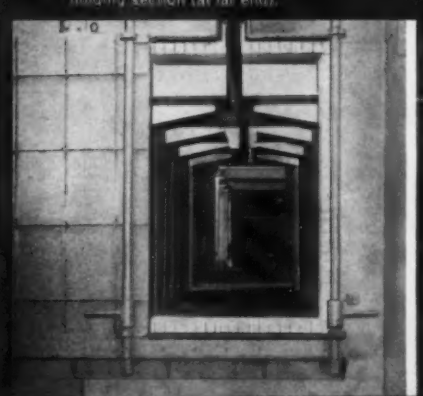
Design of unit permits convenient movement of cores through pre-heat (foreground) to holding section (at far end).



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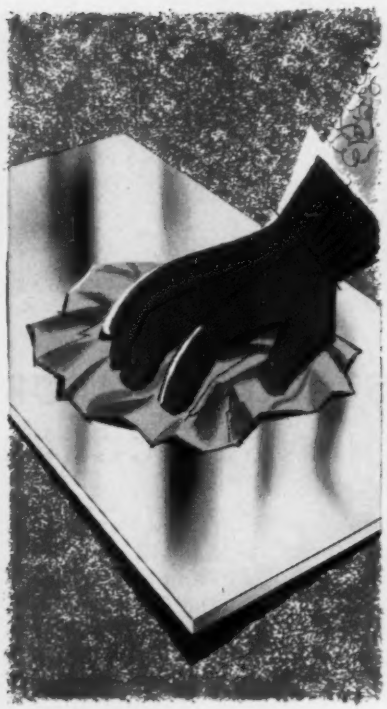

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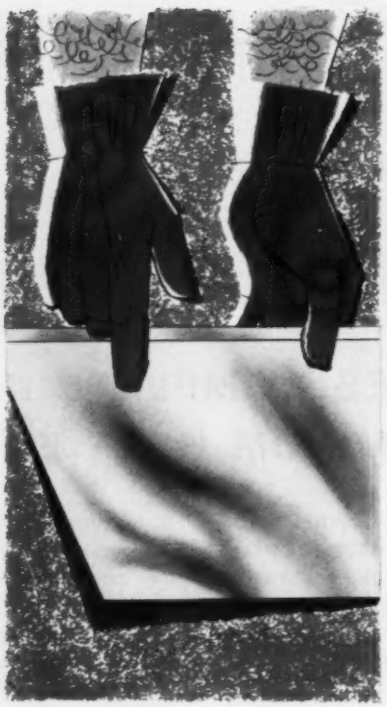

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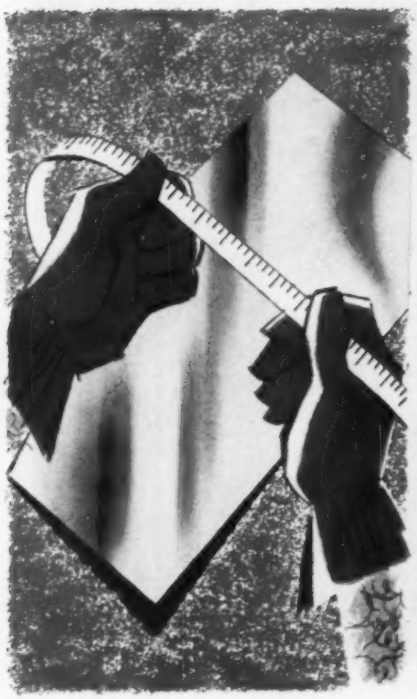
Whether your product must go through a deep draw or undergo other stringent forming operations, or if it requires a special temper for rigidity, you'll always get the correct temper for the job when you order USS Amerstrip.

WHAT YOU NEED IN A COLD ROLLED STRIP



PRECISE WIDTH TOLERANCES

When your fabricating machines require a special width strip, you can be sure that's the width you'll get with Amerstrip. We can produce USS Amerstrip within required tolerance limits to fit your special requirements.

PRECISE THICKNESS TOLERANCES

Whatever thickness tolerance your machines demand, you'll get it in Amerstrip. And it'll be precisely the same in every inch of Amerstrip ordered. Amerstrip can be rolled in thickness tolerances of plus or minus .0005 inches.

PRECISE UNIFORMITY

Regardless of the size of your order, every coil of USS Amerstrip comes off the line uniform in finish, temper, width and thickness. In short, USS Amerstrip's precision production assures a continuous run and high yield.

American Steel & Wire Representatives have the training and experience to give you expert guidance in fabrication and application of USS Amerstrip. They can show you how it contributes to a better finished product. To avail yourself of their services, call your nearest AS&W District Office. American Steel & Wire, 614 Superior Ave., N.W., Cleveland 13, Ohio.

USS and Amerstrip are registered trademarks

American Steel & Wire
Division of
United States Steel

Columbia-Geneva Steel Division, San Francisco, Pacific Coast Distributors
Tennessee Coal & Iron Division, Fairfield, Ala., Southern Distributors
United States Steel Export Company, New York

Circle 528 on Page 48-B

Never before such precise temperature control at this price!

$120 (SENSOR EXTRA)

Honeywell's new Resistance Bulb Controller responds to temperature changes as small as 0.1°, yet is modestly priced.

Honeywell's new R7087 temperature controller is a precision instrument designed for industrial use wherever temperatures must be precisely controlled: in packaging and plastics processing; plating tanks; annealing, bakery and paint-drying ovens; and in laboratory applications. Unusual flexibility is gained through a wide choice of sensors making ranges from −150° to +1400° F. possible. Centigrade scales are also available.

The new transistorized controller compensates for ambient temperature variations. Sensor connections of regular 18-gauge copper wire may be used up to 300 feet without sacrificing accuracy. Time proportioning with adjustable cycler timing is provided.

Panel lights indicate when unit is below, on or above set point. Controller can be surface-or flush-mounted, features illuminated dial. Other models are available with position proportioning.

For further information, call your local Honeywell office. Or write, Honeywell, Minneapolis 8, Minnesota. In Canada contact Honeywell Controls Limited, Toronto 17, Ontario.

Honeywell

First in Control

SINCE 1885

75th YEAR
PIONEERING THE FUTURE

Circle 529 on Page 48-B

Here's the NEW Ipsen pusher heat treating unit

Meets precise metallurgical standards in carburizing, carbonitriding, neutral hardening, sintering, normalizing, annealing and brazing.

- Each zone with individual 100% forced convection heating!
- Silicon carbide skid-type hearth fully supports light-weight trays.
- Super-alloyed ceramic tubes guaranteed one year. Ipsen "Flame-Busters" complete combustion within the heating portion of the tube.
- Both forced convection atmosphere cooling and hot-oil quench.
- Ipsen pusher units are shipped completely piped, wired, and tested.

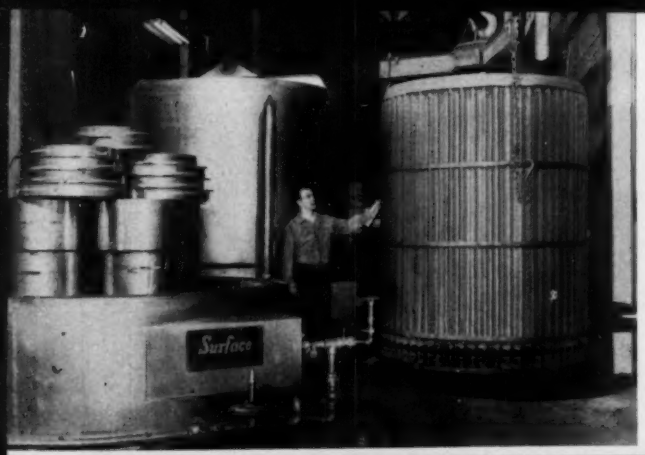
Cross-section diagrams and complete details covering all sizes of Ipsen pusher units are shown in Bulletin P-59. Send for your copy, today.

*special units available for higher temperature operation

AUTOMATIC Ipsen HEAT TREATING UNITS

IPSEN INDUSTRIES, INC. • 723 SOUTH MAIN STREET • ROCKFORD, ILLINOIS

Circle 530 on Page 48-B

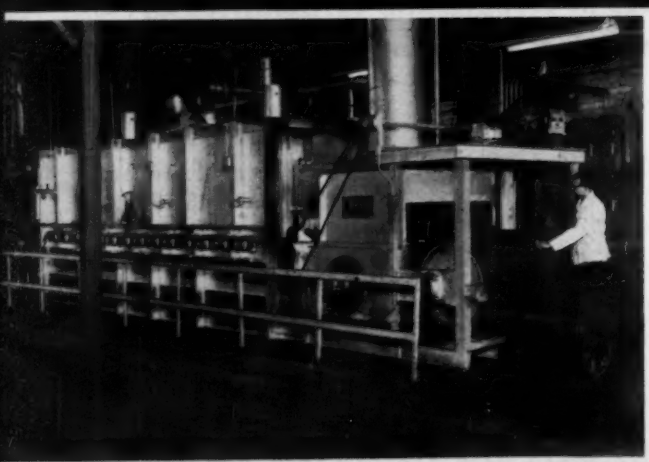


Cupro-nickel coils

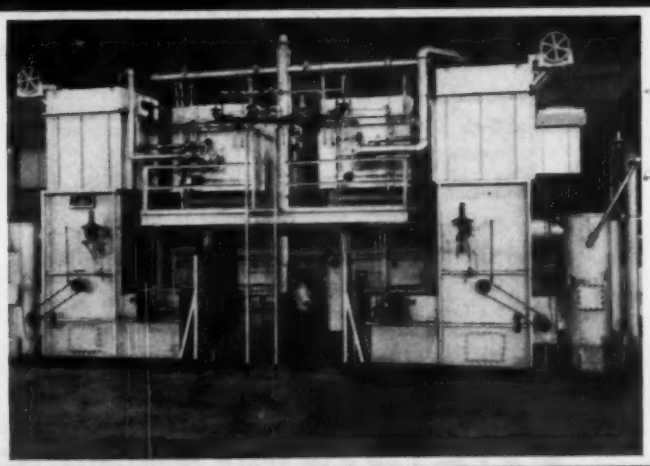
Aluminum coils

Steel gears and pinions

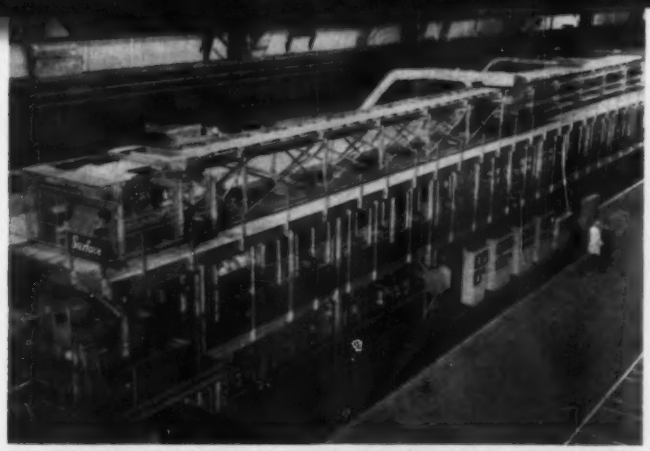
Aluminum billets



Automotive steel forgings

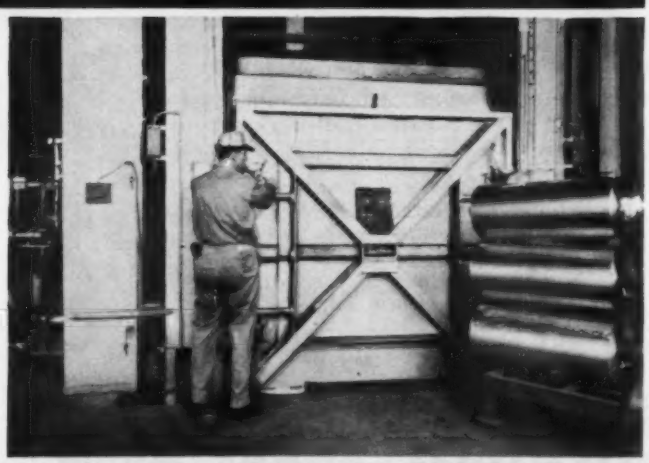


Brass tubing



Steel strip

Brass wire



Aluminum foil

How Surface Power Convection* Equipment increases speed and uniformity of heat treatment

Rates of heat transfer by radiation are limited by maximum available "thermal heads," various shapes and heat absorption properties of work pieces, and control problems which become critical when rate of heat transfer is very high.

On the other hand, heat transfer by convection can take place at rates of extreme speed, with air temperature very close to the desired work piece temperature, assuming very high air velocities.

To get such high air speeds in the first place (with fans running close to the strength and temperature limits of the best alloys available) and then use the heated air effectively in heat treating are two major problems which Surface began to tackle years ago. Gradually Surface furnaces were designed more and more like wind tunnels.

So effective are Surface's new techniques in convective heat transfer, that we can now define a furnace in terms of its **convection power**: its ability to heat the work primarily by convection, with great speed, uniformity, and efficiency.

Some of the results are spectacular; all have brought about important cost savings or product improvement. We invite you to write for Bulletin SC-182 describing Surface Power Convection equipment in more detail. Surface Combustion, 2377 Dorr Street, Toledo 1, Ohio. In Canada: Surface Industrial Furnaces, Ltd., Toronto, Ont.

*Trademark of Surface Combustion, Division of Midland-Ross Corp.

A division of Midland-Ross Corporation MR

Surface

Circle 531 on Page 48-8

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Normalizing Alloy Steels

There are several forms of heat-treatment commonly employed in the processing of alloy steels. Each in its own way modifies the mechanical properties and structures of steel, and each is chosen with a definite objective in mind. The five usual forms of treatment are normalizing, annealing, spheroidize-annealing, quenching and tempering, and stress-relieving.

In this particular discussion, let us consider briefly the purposes and effects of normalizing.

Normalizing is an operation in which the steel is heated to approximately 100 deg F above the upper transformation range, then cooled in still or agitated air. The basic purpose is to refine the prior structure produced by variations in finishing temperatures encountered in rolling or forging. The structure resulting from normalizing, being more uniform, will help create improved mechanical properties when the steel is subsequently reheated, liquid-quenched, and tempered.

There are times when large steel parts (heavy forgings, for example) cannot be liquid-quenched because of their size. In cases of this nature, the heat-treatment must consist of single or multiple normalizing followed by tempering.

High-temperature normalizing is sometimes used for grain-coarsening low-carbon alloy steels to promote machinability. (In high-temperature normalizing, steel is heated to more than 100 deg F above the upper transformation range.) At times it is possible to machine a steel in the air-cooled condition, the governing factor being the alloy content. However, the highly alloyed analyses may require annealing or tempering after normalizing, to decrease the hardness.

It is essential, when normalizing is employed, that free circulation of still or agitated air be provided. When air-cooling of individual bars or forgings is not practicable, the furnace charge should provide for some means of separation, such as racks or spacers.

If you would care to know more about normalizing, or any other phase of heat-treating, you are invited to consult with Bethlehem metallurgists. They are always glad to give you any help you need.

And remember that Bethlehem makes the full range of AISI standard alloy steels, as well as special-analysis steels and all carbon grades.

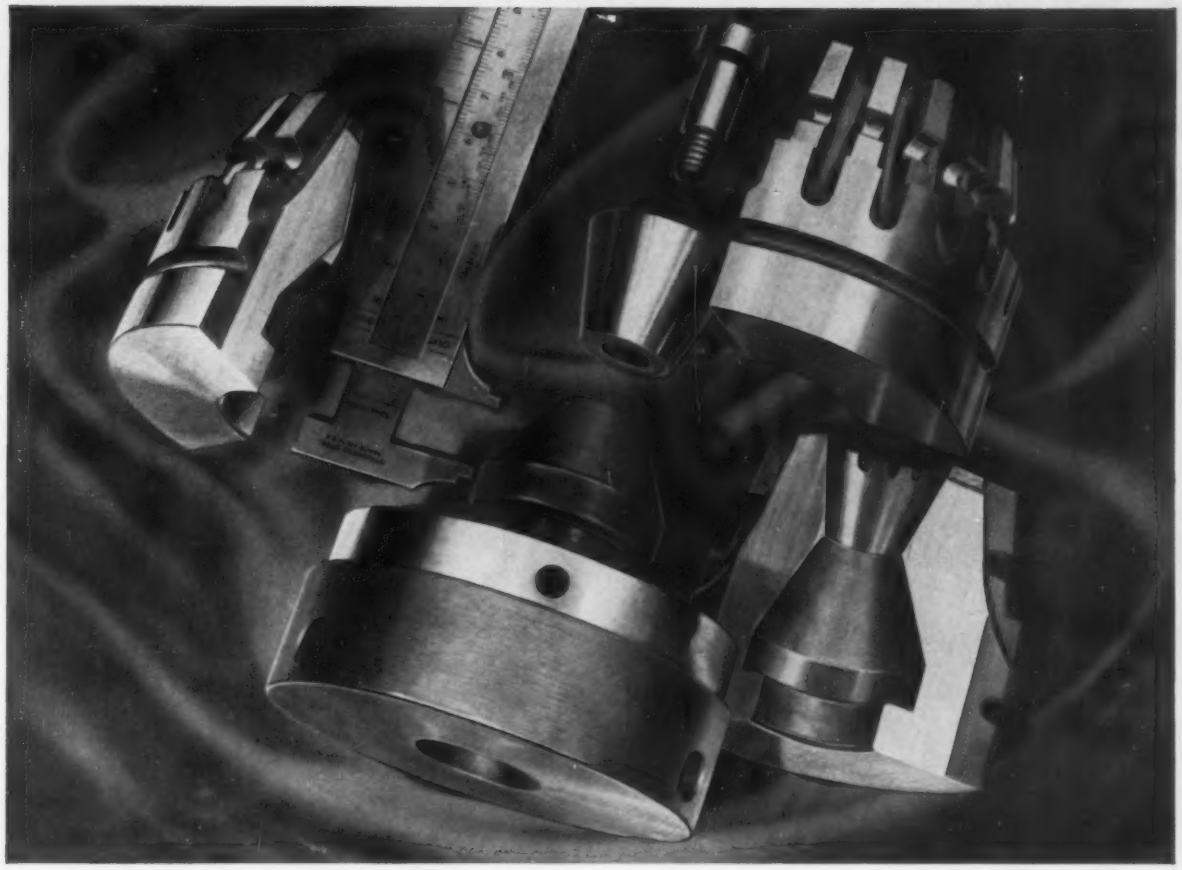
This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

Circle 532 on Page 48-B



INTRICATE SHAPES MADE EASY WITH GRAPH-AIR®

hardens at 200° to 300° lower than most air-hardening tool steels

YOU can make intricate shapes like these easier and at less cost with versatile Graph-Air tool steel. Here's why:

1) **GRAPH-AIR AIR-HARDENS FROM AS LOW AS 1450°F.** That's as much as 400 degrees lower than most air-hardening tool steels. You reduce distortion, simplify heat treating control, minimize scaling and decarburization.

2) **GRAPH-AIR MACHINES FASTER.** The free graphite in its structure makes it machine 30% faster than ordinary tool steels. Means more production for you.

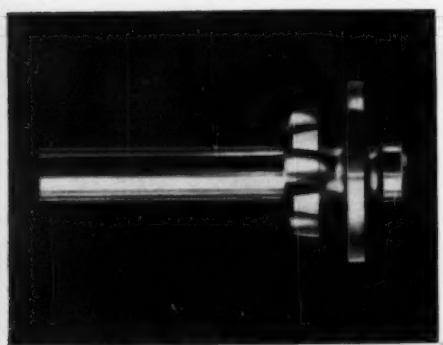
3) **GRAPH-AIR HAS MORE STABILITY.** It's one of the Timken Company's graphitic tool steels, the most stable tool steels ever made. Tests prove it. And that means longer accuracy for parts made of Graph-Air.

Uniform hardening, reduced distortion and all its other advantages allow you to machine Graph-Air into more intricate sections. It's a money-saving solution for blanking dies or other steel parts that must withstand abuse. For the best tool steel to make intricate shapes—the one that air-hardens at lower temperatures—specify Graph-Air. Available in solid and hollow bar sizes. Our metallurgists will help you select the most economical size for your needs. ***When you buy Timken steel you get...*** *1) Quality that's uniform from heat to heat, bar to bar, order to order. 2) Service from the experts in specialty steels. 3) Over 40 years experience in solving tough steel problems.* Write: The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". *Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits.*

TIMKEN® *Fine Alloy* STEEL

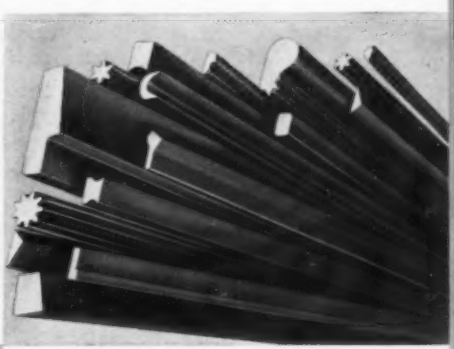
TIMKEN GRAPHITIC STEELS ARE AVAILABLE FROM STEEL SERVICE CENTERS IN 40 CITIES IN THE UNITED STATES AND CANADA

Circle 495 on Page 48-B



ONE-PIECE VALVE STEMS: National Acme Company uses Republic ENDURO® Type 303 Cold Finished Stainless Steel for Hyseal Valve Stems used in new American-Standard single-lever mixing faucets. These valve stems are completed in a single setup. Ten operations including a multiple end drilling of six holes on a 15° angle are performed in 12 seconds. For information on the more than 40 standard types of stainless steel available from Republic, mail the coupon.

AUTOMOBILE STARTER DRIVE PINIONS: Eclipse Machine Division, Bendix Aviation Corporation, uses Republic Type 8617 Cold Drawn Alloy Steel. In addition to greater strength and dependability, this alloy gives Eclipse better machinability at reasonable cost. Alloy bars are blanked, hobbed, chamfered, and drilled. Teeth are cut on a gear hobber, then pointed for easy meshing with the flywheel. Send for complete details on Republic Alloy Steel.



REPLACE COSTLY ASSEMBLIES: Republic Cold Drawn Special Section Bars are formed to the predominating cross section of your part. By eliminating or greatly reducing machining, special sections permit faster production at lower unit cost. Completed parts—*one piece parts*—are longer wearing because cold drawing improves mechanical properties. Republic Special Section Bars are available in carbon, alloy, and stainless steel. Send for additional information.

Republic's

CENTURY SERIES...

MINIMUM YIELD STRENGTH 100,000 PSI

...5 grades, 5 degrees of machinability, 5 price levels!

To save time and money in steel parts production, choose from this family of five grades of high strength, stress-relieved, cold finished steel bars.

Republic's CENTURY SERIES provides varying degrees of machinability. Yet, each grade—C-1045, C-1050, C-1151, C-1141, and C-1144—offers minimum yield strength of 100,000 psi. Better strength/toughness ratios are frequently obtained by selecting one of the lower sulphur, *less expensive* grades. Return the coupon for your free copy of Republic's CENTURY SERIES Booklet.

REPUBLIC STEEL

World's Widest Range of Standard Steels and Steel Products

Circle 496 on Page 48-B

REPUBLIC STEEL CORPORATION
DEPT. MP-9663-C
1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

Please send more information on:
- ☐ CENTURY SERIES
- ☐ Cold Finished Stainless Steel
- ☐ Special Section Bars
- ☐ Republic Alloy Steel

Name_____ Title_____

Company_____

Address_____

City_____ Zone_____ State_____

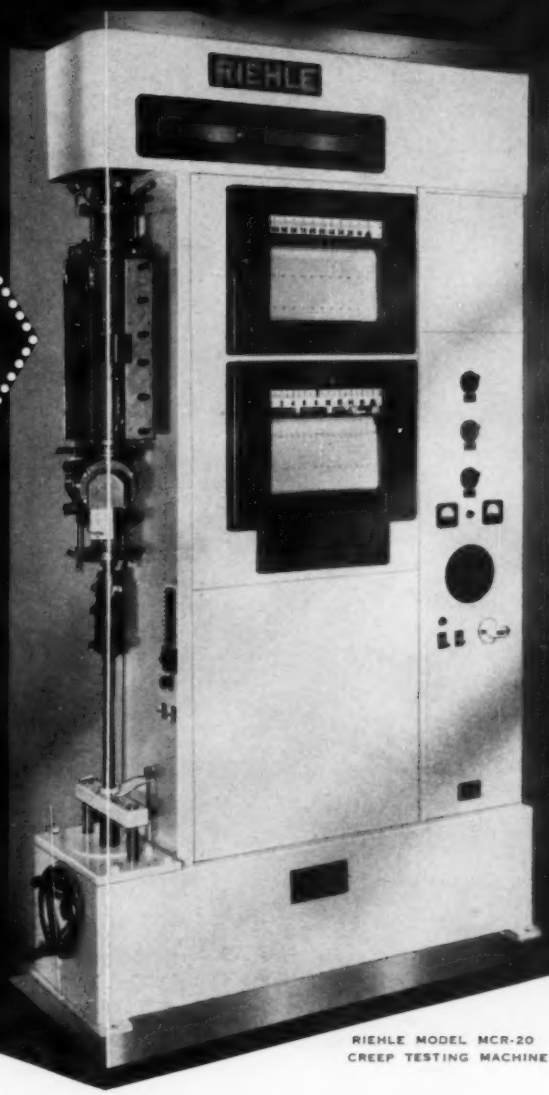
FROM

RIEHLE

one complete package

FOR
HIGH TEMPERATURE CREEP
AND RELAXATION TESTING
including full instrumentation for
wide range of testing applications

BATTERY INSTALLATION OF RIEHLE HIGH TEMPERATURE CREEP TESTING MACHINES



RIEHLE MODEL MCR-20
CREEP TESTING MACHINE

COMPLETE systems of equipment for testing physical properties of materials at temperatures as high as 4000° F can be obtained from ONE source — RIEHLE TESTING MACHINES.

These ready-to-operate systems include:

- BASIC TESTING MACHINE
- STRAIN MEASURING INSTRUMENTATION
- COMPLETE HIGH TEMPERATURE ACCESSORIES

Using only 33⅓ lbs. of weights, this RIEHLE Model MCR-20 features a multiple lever loading system to provide testing loads in increments of 1,000 lbs. A sliding poise and beam graduated in units of 10 lbs. provide intermediate loads.

This machine can accommodate complete equipment for high temperature vacuum testing at 3000° F and 4000° F. All equipment needed to perform this testing is mounted within the testing machine frames.

RIEHLE CREEP AND RELAXATION TESTING MACHINES are available in open atmosphere temperatures up to 2800° F. Vacuum or controlled atmosphere temperature steps are 2000° F, 2400° F, 3000° F and 4000° F.

Send RIEHLE engineers your requirements for any special problems in physical testing at elevated temperatures. Their assistance can save important project time. Address inquiries to Dept. MP-760.

CREEP AND STRESS RUPTURE TESTING MACHINES • HYDRAULIC FATIGUE TESTING MACHINES • HYDRAULIC UNIVERSAL TESTING MACHINES • UNIVERSAL SCREW POWER TESTING MACHINES

Circle 497 on Page 48-B

Riehle® TESTING MACHINES

A DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

"One test is worth a thousand expert opinions" TM

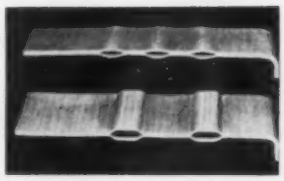
Divisions of American Machine and Metals, Inc.

TROY LAUNDRY MACHINERY • RIEHLE TESTING MACHINES • DE BOTHEZAT FANS • TOLHURST CENTRIFUGALS • FILTRATION ENGINEERS • FILTRATION FABRICS
NIAGARA FILTERS • UNITED STATES GAUGE • RAHM INSTRUMENTS • LAMB ELECTRIC COMPANY • HUNTER SPRING COMPANY • GLASER-STEERS CORPORATION

NEW PRODUCTS

Nonferrous Metals

"Roll-Bond" Sheet



An improved Roll-Bond sheet made of two different aluminum alloys has been announced by *Olin Mathieson Chemical Corp.* One side of this "tube-in-sheet" is a harder alloy, which has about twice the tensile strength of the mating sheet. After bulging, the harder sheet has a flatter contour (top photo), which is of considerable advantage in, say, the inside of the freezer compartment in refrigerators – making it easier to remove trays and containers. The stronger alloy also resists puncture damage, which should reduce service and repair costs. This product can be used in a variety of heat transfer applications, such as de-icers for airplanes, and equipment for maintaining controlled temperatures – particularly where space is limited. Roll-Bond sheets can also be formed of copper alloys.

For further information circle No. 200 on literature request card, p. 48B.

Ductile Permanent Magnet Alloy

An improved "Cunife" copper-nickel-iron permanent magnet alloy is ductile, malleable, and machinable. It can be formed into complex shapes impossible to produce with hard and brittle cast or sintered materials. Application experience in electronic equipment and control systems indicates a low cost per unit of useful magnetic energy is obtained. The alloy is available in the form of finished magnets for specific design requirements, or as wire and strip in a range of sizes and shapes. *Hoskins Mfg. Co.*

For further information circle No. 201 on literature request card, p. 48B.

Heat and Corrosion Resistant Materials

Refractory Metal Coating

An electron beam unit can vaporize all metals including the high melting point refractory elements such as tungsten, tantalum, columbium, and molybdenum. "Model EBV-3" may be used for research work or production of thin-film coatings where vacuum equipment operating at 3×10^{-4} mm. of Hg is available. The unit includes the electron beam gun, power supply, and control panel. It is rated 250 milliamp. at 10 kv. and operates on standard 120-v., 60-cycle, 15-amp. power. A motor-driven feeder for supplying metal is optional. *Alloyd Corp.*

For further information circle No. 202.

Tool Materials

Metal-Cutting Torch

The "Oxweld C-66" natural gas cutting torch can slice through 30 in. of metal in a single pass. It can handle all cutting jobs in steel mills, scrap yards, or foundries because of the large preheat capacity and oxygen flow rate (3000 cu.ft. per hr.). It is ideal for removing large risers. Operating costs of the "C-66" are 15% lower than other torches due to faster starting and cutting. Over 40 nozzles can be used with this torch, for scarfing, gouging, and rivet piercing. Bendable, long-length nozzles for "hard-to-get-at" places are also available. *Linde Co.*

For further information circle No. 203 on literature request card, p. 48B.

Industrial Heating

Induction Heating Machine

The "building - block" design of this machine permits transfer of units from one production line to another and also saves valuable floor space. A portable monitor - control panel is mounted on a portable heating station. A scanning mechanism, which includes limit-switch control of heat and quench cycles and preset feed rates, transports and spins the part through the heating coil. The power is supplied by a vertical motor-generator set. In capacities from 7½ to 30 kw., the heating station includes a high-frequency line contactor. A 50-kw. heating unit is also available. *Cincinnati Milling Machine Co.*

For further information circle No. 204 on literature request card, p. 48B.

Annealing Stainless Strip

An electric furnace for continuous bright annealing of stainless steel strip has attained production rates as high as existing anneal and pickle lines, and at a 50% lower cost per ton. Improved corrosion resistance, appearance, and properties are claimed for the annealed strip. The formation of scale is prevented by a pure, dry (−60° F. dew-point) hydrogen or dissociated ammonia atmosphere. The strip goes through the vertical furnace in an inverted "U" pattern. On the downward pass, it is rapidly heated to annealing temperature by direct radiation from molybde-

32,000 technical management readers await

THE Metal Progress OCTOBER METAL SHOW ISSUE

their response makes it your most important single metalworking advertising opportunity of the year!

PREVIEW OF CONTENT

BEHIND THE OCTOBER ISSUE:

"Manufacturers in the metalworking industry are faced with a severe problem of keeping costs in line to stay competitive. There is pressure from increasing wages and higher-cost materials, yet boosting prices isn't easy in the present state of competition. This means that management must look to improved technology for programs designed to cut costs and step up efficiency of their operations. More than ever before the **technical management men** of the metalworking industry will be seeking vital information, such as presented in this special report, to guide them in selecting the metals they use, their fabrication and processing." — THE EDITORS OF METAL PROGRESS

RESERVE SPACE NOW

— capitalize on increased reader attention produced by METAL PROGRESS, dominant in its editorial coverage of Metal Show subjects.

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report to technical management:

THE METALS TECHNOLOGY OF THE SIXTIES

PROGRESS IN STEELS Improved Materials — Alloy, Carbon, Leaded, High Strength, Superstrength, Stainless

PROGRESS IN STEELS Forming — Advances in Production Practices for Stamping and Drawing Steels

PROGRESS IN STEELS Welding — Advances in Production Practices for Welding Carbon & Alloy Steels

PROGRESS IN STEELS Heat Treatment — Modern Quenching Techniques Bring Out Improved Properties in Steels

PROGRESS IN STEELS Hardenability Bands for Three New Standard H-Steels

PROGRESS IN MATERIALS and Process Applications in the Automotive Industry

PROGRESS IN HIGH TEMPERATURE ALLOYS

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PROGRESS IN COPPER BASE ALLOYS

PROGRESS IN MAGNESIUM ALLOYS

SPECIAL METAL SHOW SECTION Complete Guide to Exhibits, Detailed Program of Technical Sessions, Digests of ASM Papers

num heating units (muffleless construction). In the cooling chamber, the strip is rapidly cooled by high-velocity jet cooling with hydrogen or dissociated ammonia. The furnace can anneal (2000° F.) 0.020-in. Type 430 stainless strip at 60 ft. per min. For 24-in. wide strip, the capacity would be 6000 lb. per hr. *General Electric Co.*

For further information circle No. 205 on literature request card, p. 48B.

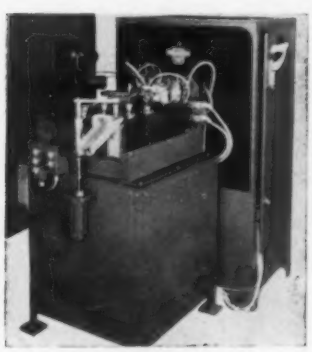
Induction Melting Unit

A 100 kw. induction melting unit has been introduced by *Inductotherm Corp.* The console contains the motor-generator, capacitors, and the control and safety devices for operating one or two high-frequency induction furnaces, or heating coils. For maximum flexibility in meeting any heating or melting requirement, an eight-step auto-transformer and 30 steps of capacitance values are contained in the unit. A 60-cycle, 440-v. power supply, a cold water connection and a water drain are required for installation. One or two heating coils, or furnaces with capacities up to 500 lb., can be connected to the "Integral 100" unit with water cooled leads.

For further information circle No. 206 on literature request card, p. 48B.

Hardening Trunnion Bearings

Trunnion bearings can be internally hardened (bottom and inside diameter) with a "Ther-Monic" automatic induction heating machine. The rotating work station has eight spindles, each of which is, in turn, positioned beneath the heating coil. A tolerance of ±0.0015 in. can be maintained after

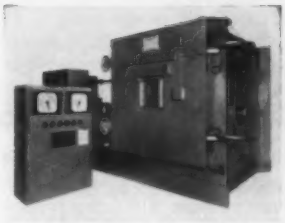


hardening. Complete operating controls for the 25-kw. generator and the work station are included. *Induction Heating Corp.*

For further information circle No. 207 on literature request card, p. 48B.

Environmental Test Chamber

Simulating conditions encountered in outer space, this chamber produces both high (1000° F.) and low (−100° F.) temperatures by radiation from all sides, as well as by convection. At any simulated altitude up to 150,000 ft., the gradient, at any given temperature, can be held to ±5° F. The chamber, with internal dimensions of 4 × 4 × 4 ft., is equipped with mechanical refrigeration capable of dissipating a heat load at the rate of 7500 watts at −70° F. *American Research Corp.*



For further information circle No. 208.

Cleaning and Finishing

Insoluble Anodes

A platinum-coated titanium-mesh anode, which costs about one-tenth as much, is said to be functionally equal to a solid platinum anode. "Platanium" anodes may be used for any insoluble anode application – from electroplating to refining and chemical processing. One company has operated an electrolytic brine cell continuously for two years with no breakdown of the "Platanium" anodes. *Sel-Rex Corp.*

For further information circle No. 209 on literature request card, p. 48B.

Automatic Wheel-Wear Adjustment

An electronic adjustment device, which automatically compensates for buffing or grinding wheel wear in high-production finishing operations, produces a more uniform finish, lowers buffing or grinding compound costs, and reduces wheel wear. The "Adjusta-Matic" device is included with all new machines built by the *Packer Machine*

Save Time—Save Labor—Save Material

with Steel City Ductility Testers

Test incoming material for drawing qualities to be sure it will do the job for which you bought it and you'll avoid scrap and eliminate costly wasted effort. How? With a Steel City Ductility Testing Machine. Two concentric pistons do the job. Outer piston grips test piece against head; inner piston makes the cup. Gripping and load application are automatic. Piston speed is easily adjustable.

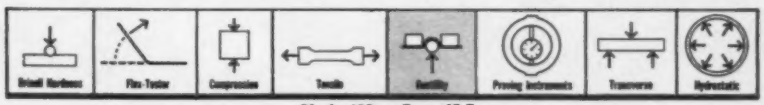
Distributors in most major metalworking areas

Steel City Testing Machines Inc

8811 Lyndon Ave., Detroit 38, Mich.

Available in two compact floor models for thicknesses up to ⅛" and ¼", and a bench model for thin metals 0.001" to 0.062". Hydraulic capacities up to 40,000 lb. Specimens up to 4" wide tested with ease. Depth indicator incorporates friction brake to hold readings. Easy-to-read load gage has maximum-indicating hand. Write for detailed specifications.

Write or call Steel City if you have any special testing problems



Circle 498 on Page 48-B

Quality control at Standard is second to none among the nation's major specialty product steel plants. It is maintained by the most accurate, up-to-date testing equipment available. The laboratory facilities operate around the clock to keep all vital information flowing to our metallurgists, shop foremen, mill and machine operators—as well as to plant management, and, of course, our customers.

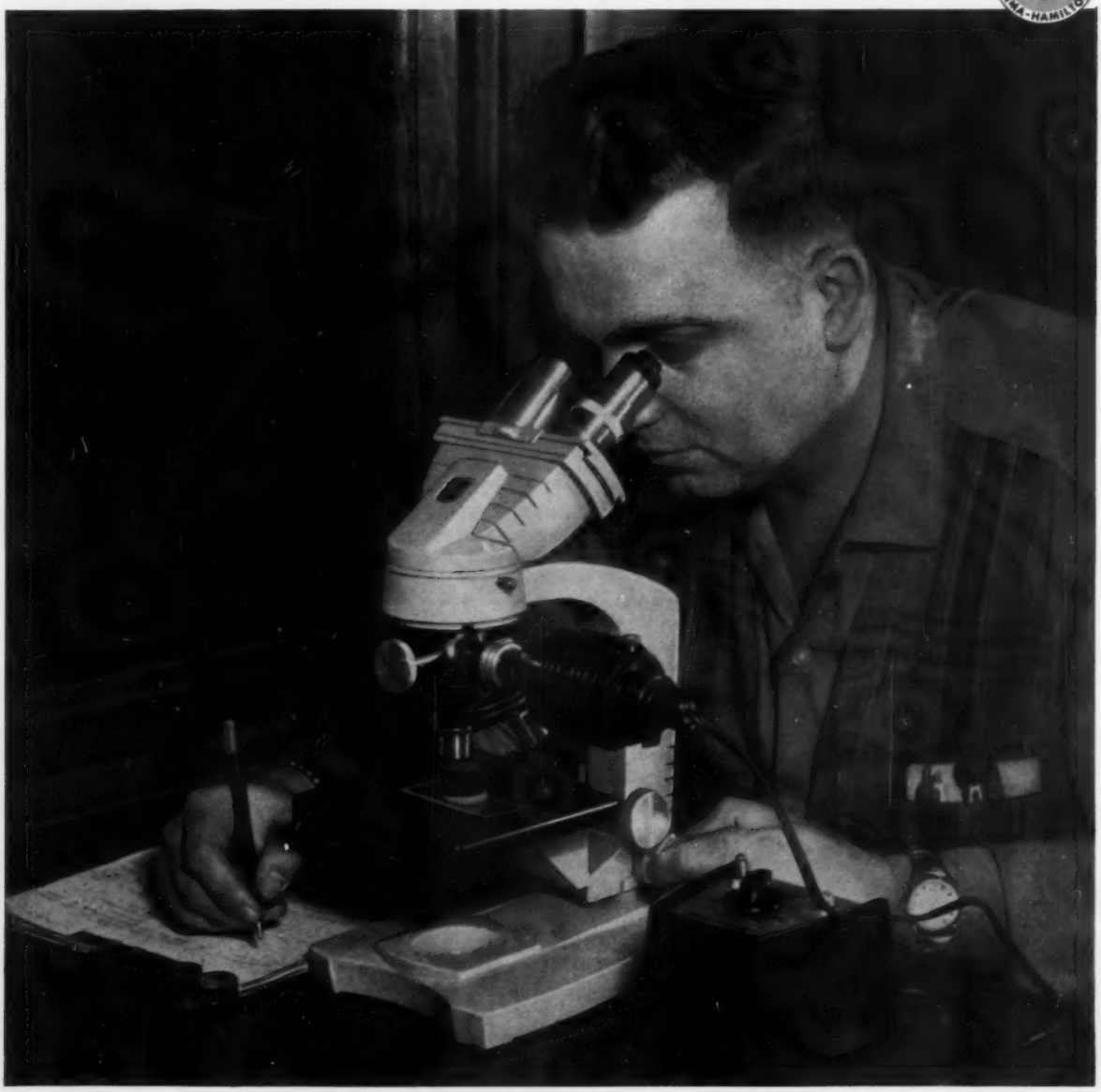
Bring your next unusual product to us—we'll welcome the opportunity to serve you regardless of the alloy it might require. Send for the free illustrated booklet, "Quality Control at Standard."

Standard Steel Works Division

BALDWIN · LIMA · HAMILTON

BURNHAM, PENNSYLVANIA

Rings • Shafts • Car wheels • Gear blanks • Flanges • Special shapes



Circle 499 on Page 48-B

Co., and can be installed on units already in plants. The Adjusta-Matic maintains the operating efficiency of the machine by controlling the current demand between preset limits. The device senses large current demands and re-positions the wheel to maintain the lowest possible power consumption.

For further information circle No. 210 on literature request card, p. 48B.

Sludge Removal System

The illustrated side-zone sludge removal system allows continuous cleaning, descaling, or paint stripping – with no costly salt pot cleaning required. Features of the system are turbulent agitation of the bath and control of direction and flow rate of the salt charge through the four interconnected zones: (*a*) agitation, (*b*) work, (*c*) sludge settling, and (*d*) heating. Sludge is removed from the settling zone with no lost production time. Sludge does not settle in the work zone or on the burner tubes; improved heat transfer and efficiency, and longer life are obtained. *Kolene Corp.*

For further information circle No. 211 on literature request card, p. 48B.

Portable Filter for Electroplating Solutions

A portable, side-opening filter, which eliminates solids from nickel, copper, cadmium, and zinc plating solutions, is made by *Udylite Corp.* Hollow filter plates, set vertically in the "Series 60" filter, provide greater filtration area which permits efficient

operation at a lower speed and pressure. All plates can be quickly removed for cleaning. There are eight filter sizes, from 200 to 10,000 gal. per hr. Depending on size, positive displacement or centrifugal pumps that develop up to 28 psi. are employed.

Circle No. 212 on card.

Welding

Arc Welding Cast Iron

Eutectic Welding Alloys Corp. has revealed a three-step process for arc welding cast iron in one-tenth the time required by other methods. Weld metal deposited from a new electrode can be quenched without cracking; pre-heating and slow cooling between weld passes are therefore eliminated. In the first step, a chamfering electrode, "ChamferTrode", gouges out the area to be welded – minimizing the possibility of stress concentration cracks developing. A "EutecTrode 27" sealing electrode is used in the second step to coat the weld area with a thin deposit and reduce weld contamination. It prepares the surface for a strong bond between the cast iron and the weld deposit. In the third step the weld is completed with a "QuenchTrode 24" electrode. The weld deposit is low in carbon and is tough enough to be quenched without cracking. Each pass is quenched with water as soon as it is completed, eliminating the time consuming air cooling required by other methods. The process can be used on any cast iron, except chilled iron and Ni-Hard, for repairing castings, filling holes, building up worn surfaces, or joining cast iron and steel.

For further information circle No. 213 on literature request card, p. 48B.

Strip Welder

Semi-automatic butt welding of rolling mill strip, 1 to 8 in. wide and 0.020 to 0.125 in. thick, has been announced by *National Electric Welding Machines Co.* The equipment is designed for a standard inert-gas-shielded tungsten-arc welding torch. With an inert-gas-shielded consumable electrode welding head, strip up to ⅜ in. thick can be welded. Typical welding speeds are 20 in. per min. on 0.020-in. stock and 6 in. per min. on ⅛-in. stock. Minimum buildup and 100% weld penetration produce a stronger weld joint than obtained with stapling or overlap spot welding. Mild or stainless steel, copper, brass, or galvanized strip can be joined.

For further information circle No. 214.

REPAIR DAMAGED
VACUUM MELTING CRUCIBLES

SAVE TIME AND MONEY

Zak offers experienced service in the repair of crucibles and ingot molds damaged through handling mishaps or other causes.

Typical customer comment has been—"we saved money—down time was cut — our crucible was back in production ahead of schedule."

Manufacturers and Fabricators of:
- VACUUM FURNACES
- VACUUM or CONTROLLED ATMOSPHERE CHAMBERS
- SKULL MOLDS
- VACUUM CRUCIBLES
- HOT TOPPING UNITS
- INGOT MOLDS (STEEL AND COPPER)

FOR RESEARCH OR PRODUCTION

For service call:
Troy **ARsenal 3-3912** *and save!*

Send for descriptive literature:
BU-58 Button Furnace • Cr-58 Crucible • FAC-58 Facilities Folder • IM-59 Ingot Molds • HT-59 Hot Topping Unit

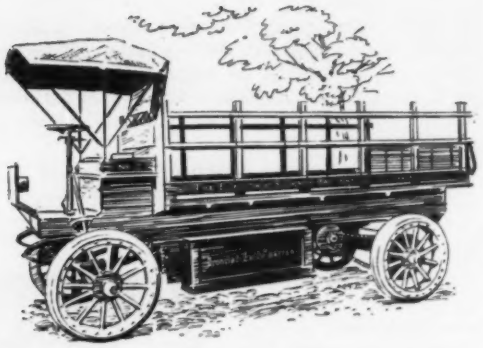
ZAK MACHINE WORKS, INC.
"Engineering Manufacturers for Industry"
TROY (GREEN ISLAND) NEW YORK

Circle 500 on Page 48-B

LEAD

Sparks A

RENAISSANCE

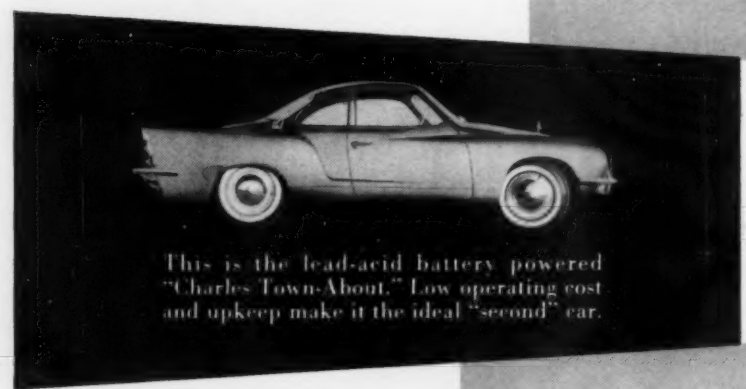


Lead Storage Batteries

Provide *Practical Power*

For Trucks, Cars and Toys

Tests have shown that this Cleveland Vehicle Company's Electric Delivery Truck for stop-go routes saves up to 50% operating costs . . . up to 55% upkeep costs . . . up to 50% insurance costs.



This is the lead-acid battery powered "Charles Town-About." Low operating cost and upkeep make it the ideal "second" car.

Look Ahead

With ***LEAD***

"BABY FERRARI" Bimbo Racer 12, exact miniature of the Ferrari Italian sports car, is powered by a standard 12 volt lead auto battery, runs at 5 to 7 miles per hour, climbs 20% grade, operates five to six hours continually before recharge. Built-in recharger uses regular house current, recharges overnight.

ST. JOSEPH LEAD CO.

ST. JOE

250 PARK AVENUE •
NEW YORK 17, NEW YORK

The Largest Producers of Lead In The United States

PB-148

Circle 501 on Page 48-B

Inspection and Control

Universal Tester

This automatic testing system consists of a standard universal testing machine plus encoders and memory storage units. The system automatically converts normal graphic test information directly into digital printing. Thus high-volume, high-speed testing, such as found in quality control and statistical research testing, can be done accurately with a substantial savings in

technical manpower. The system will print out values of maximum load, breaking load, total extension, and total energy to break. It automatically returns the crosshead to gage length for the next test. The digital system has flexibility; it can be adapted to a variety of test requirements. *Instron Engineering Co.*

For further information circle No. 215 on literature request card, p. 48B.

"Out-of-Tolerance" Indicator

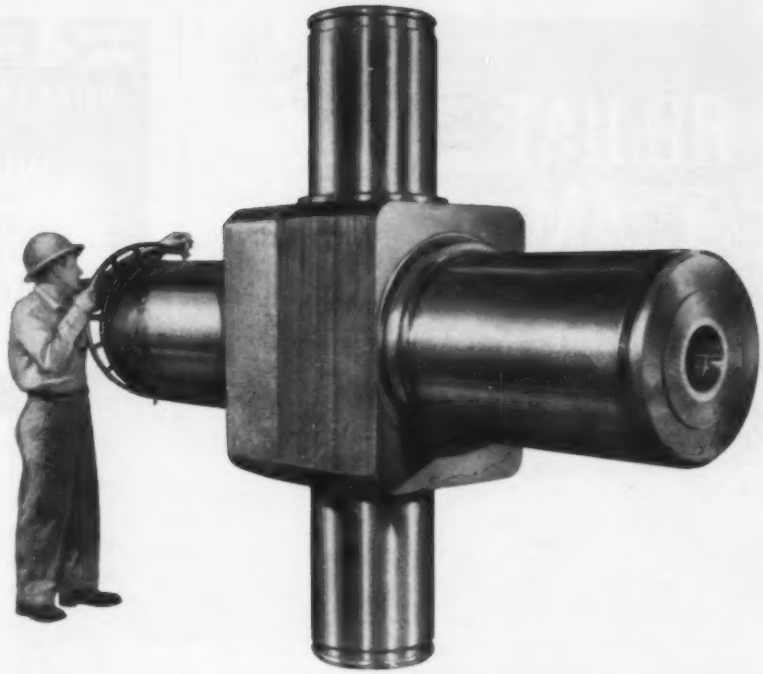
Hamilton Watch Co. is offering a "Kwik-Chek" electric indicator which signals when tolerance limits are exceeded. The signal is used to actuate automatic control devices. When gaging more than one dimension, a summarizing box is added to the system. If an "out-of-tolerance" condition exists on any of six dimensions, an "over" or "under" signal will light.

For further information circle No. 216 on literature request card, p. 48B.

Production and Casting

Vacuum Degassing in Foundry

F. J. Stokes Corp. has developed a series of degassing equipment in a range of sizes from 150 to 3000 lb. capacity. The equipment consists of a bell – similar to a stream-degassing dome – which is placed over



13½ TON EQUALIZING AXLE from BLUEPRINT to FINISHED PART by FINKL

This 27,000 pound steel forging,* made to support a million pound load, was completely manufactured from molten steel to a finished machined part in the Finkl shops.

A 115,000 pound electric furnace steel ingot was cast, forged, hot cut and heat treated, followed by hundreds of hours of rough and finished machining. Then the square section was heated to accept the horizontal part to complete the shrinking operation to make this equalizing axle.

Finkl is well-equipped to engineer and produce a wide range of forged parts . . . our sales engineers will be pleased to talk to you about your forgings, hot work steels and die block needs.

*Replaced a casting

DIE BLOCKS · FORGINGS · HOT WORK STEELS · ELECTRIC FURNACE STEELS

Manufacturers of the
largest forgings in the Middle West

A. Finkl & Sons Co.

2011 SOUTHPORT AVENUE • CHICAGO 14, ILLINOIS

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ST. PAUL • COLORADO SPRINGS • SAN FRANCISCO • SEATTLE • BIRMINGHAM • KANSAS CITY
BOSTON • LOS ANGELES Warehouses in: CHICAGO • DETROIT • BOSTON • LOS ANGELES

Circle 502 on Page 48-B

CHICAGO
Mr. Paul W. Wendt & Sons
431 S. Dearborn St. Rm. 401
Chicago, Illinois

DETROIT
Mr. H. E. Evans
336 Dover Road
Pontiac, Michigan

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C. W. Hunt & Son
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San Francisco 5, California

PITTSBURGH
Mr. Ronald R. States
R.D. #3 Richland Road
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LOS ANGELES
McGowan Company, Inc.
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Los Angeles 23, California

CANADA
Mr. Stephen S. Barber
1415 St. Mark Street
Montreal, Quebec
Canada

BUFFALO-ROCHESTER
Messrs. Bert Tidd & I. P. Ridley
P. O. Box 24
Auburn, New York

Mr. L. S. (Sid) Hancock
1201 Venables Street
Vancouver 6, B.C.
Canada

NEW YORK
Mr. Paul Schlesinger
(Pavelle Trading)
220 West 42nd Street
New York 36, New York

Diversified Research
& Sales Ltd.
151 Belfield Road
Rexdale, Toronto, Ont.
Canada

Send for booklet "The Biggest Ounce of Protection."

*Any of these sales engineers will gladly help you with your own lubricating and related problems, and prove to you the value of GRAFO Colloidal Dispersions for improving production.

GRAFO COLLOIDS *Corporation*
Wilkes Place, Sharon, Pa.

Circle 503 on Page 48-B

REVCO

ULTRA-LOW TEMPERATURE CABINETS

for

- Research
- Storage
- Seasoning
- Testing

Seven Revco cabinets, both chest and upright styles, are available. Capacities range from 1.5 to 6 cu. ft. in chests and to 22 cu. ft. in uprights. Units provide temperatures to −140° F. controllable within ±1°. Optional accessories are offered. Immediate delivery on all units.

For your FREE copy of the helpful folder, "Selecting a low temperature cabinet," write Revco, Dept. MP-70.

Industrial Products Div.,
REVCO INC.
Deerfield, Michigan
Setting Trends in Refrigeration Since 1938

Circle 504 on Page 48-B

Industry's NEWEST Production TOOL

MOLYKOTE® G LUBRICANT

- ALMOST 100% SAFETY AGAINST GALLING AND SEIZING WITH ALL BEARING METAL COMBINATIONS
- ELIMINATES STICK-SLIP, METAL PICK-UP AND DISTORTION IN PRESS FITTING
- REDUCES WEAR-IN TIME AND DAMAGE IN NEW OR REBUILT MACHINERY
- THE HIGHER THE LOADS, THE GREATER THE MARGIN OF SUPERIORITY OF MOLYKOTE G

Write for your free sample of MOLYKOTE G LUBRICANT today. We will also send you a copy of our new Bulletin 126 which gives complete details. THE ALPHA-MOLYKOTE CORPORATION, 65 Harvard Avenue, Stamford, Conn. Phone Fireside 8-3724. Plants in Stamford, Conn., Munich, Germany and Strasbourg, France.

THE ALPHA-MOLYKOTE CORP.
65 Harvard Ave., Stamford, Conn.
Please send me a free sample of your MOLYKOTE G Lubricant.
NAME_____
COMPANY_____
ADDRESS_____
CITY_____ ZONE____ STATE_____

Circle 505 on Page 48-B

COLUMBIA TOOL STEELS

EXTRA HEADERDIE (type W1-2D)
The fastener industry's first choice die steel

Product of Skilled American Workmen

COLUMBIA TOOL STEEL COMPANY
440 Lincoln Highway
Chicago Heights, Illinois

TOOL COLUMBIA STEELS

an induction melting furnace to form a closed chamber. The metal is melted and alloyed in air, and then is placed under reduced pressure – 500 microns to 10 mm. – and held for 15 to 30 min. to remove gases. The pressure should be reduced slowly to prevent excessive boiling and spattering. Pouring is done in air. Advantages of degassed metal are improved surface finish and internal soundness. In addition, the ability to generate a "carbon boil" minimizes carbon pickup. The advantages of vacuum-degassed metal are particularly important in foundries producing large forging ingots and roll castings.

For further information circle No. 218 on literature request card, p. 48B.

Silicone Mold Spray

Containing pure silicone and a chemically inert propellent, "Sprayon No. 205" mold release is suitable for all types of molds. The extremely low surface tension of the spray coating is responsible for the maximum release effect. Rejects are cut to a minimum, and marking, spotting, and sticking are reduced. The coating also acts as a water repellent on most porous surfaces. The mold release spray is packed in a 12-oz. aerosol can for economical application. *Sprayon Products, Inc.*

For further information circle No. 219

Brass and Bronze Pellets

The need to pile, pick up, carry, lift, and throw ingots is eliminated when pellet handling and charging is introduced. This makes it possible to store, handle, and charge copper-base alloys by means of bins, hoppers, pipes, and feeders. Metal quality is improved, melting losses are not increased, and melting is faster and less costly. In addition, pellet charging permits closer control of chemical composition, and greater uniformity of product is obtained. *I. Schumann & Co.*

For further information, circle No. 220 on literature request card, p. 48B.

Parts, Forms, and Shapes

"Zippertubing"

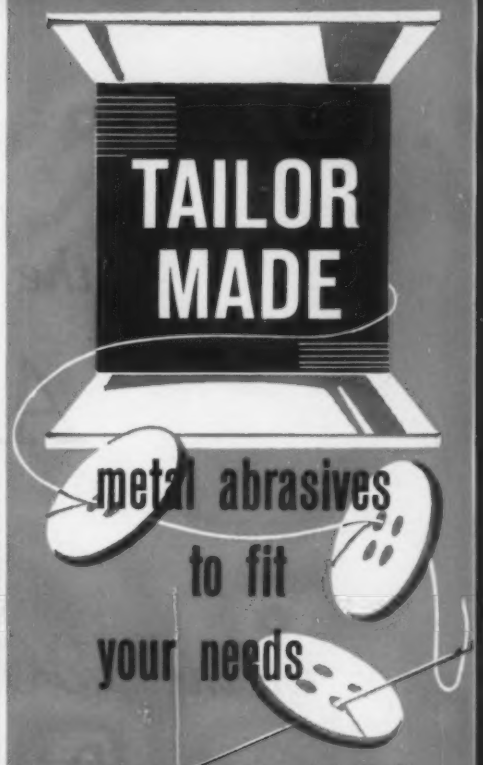
The stainless tubing shown protects cables and wires from extreme wear and abuse in industrial environments. It offers positive protection against abrasion and will even shield against shrapnel from explosive charges. Zippertubing comes in sheet or strip form and is made into tubing on the job without the help of special dies, guides, rollers, or other equipment. It offers a considerable material and labor savings. No special skill is required and only one operator is needed to apply the tubing. *The Zippertubing Co.*

For further information circle No. 221 on literature request card, p. 48B.

Extrusions and Die Forgings

By employing hot or cold extrusion, and hot die forging, a variety of complex shapes can be produced in copper, beryllium, columbium, titanium, zirconium, zinc and their alloys. Advantages of extrusions and die forgings are lower cost, improved quality and properties, and reduced machining. The *Janney Cylinder Co.* has equipment for inspecting by zyglo, X-ray, or ultrasonic means, and is also equipped to heat treat and finish-machine extruded or forged parts.

For further information circle No. 222 on request card, p. 48B.



It is no longer necessary for you to buy and use general purpose metal abrasives on the basis of claims made by its manufacturers of its performance in other plants.

Now you can have "Malleabrasive" shot or grit formulated to fit the needs of your own particular product, cleaning equipment and operating conditions.

The flexibility of our process of making "Malleabrasive"—and it's ours *exclusively* . . . new techniques and specialized equipment new to the metal abrasive industry enable us to make the type of "Malleabrasive" that will do your cleaning job best.

If you are interested in pinpointing maximum cleaning efficiency and lowest blast-cleaning costs in your own plant, "Malleabrasive"—*tailor made for you*—will do both. Write for full information.

THE GLOBE STEEL ABRASIVE CO.
Mansfield, Ohio

Sold by many leading distributors of foundry supplies from coast to coast.

Circle 304 on Page 48-E

MALLEABRASIVE

the most DYNAMIC ATTRACTION

a show ever had!

at the 1960 PHILADELPHIA

42nd NATIONAL METAL CONGRESS & EXPOSITION

Philadelphia Trade and Convention Center • Oct. 17-21, 1960

EXHIBITORS FROM ELEVEN METALS AREAS

1. Ferrous Metal Producers and Distributors
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3. Related Engineering Materials
4. Nuclear Materials and Equipment
5. Tool Materials, Cutting-Off and Forming Equipment
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7. Cleaning and Finishing Equipment and Supplies
8. Welding and Joining Equipment and Supplies
9. Testing, Inspection and Control Equipment and Supplies
10. Production and Casting Equipment and Supplies
11. Parts, Forms and Shapes for Design and Applications

Exhibitors at the Philadelphia Metal Show will gather their customers and prospects from the broad metalworking industry, including automotive, aircraft, appliance, ordnance, farm machinery, electrical machinery, instruments, and miscellaneous metalworking manufacturers . . . creating a thriving, effective, profitable marketplace. If your potential for sales lies in any of these areas, the Metal Show should take priority in your sales plan for maximum impact in the Soaring Sixties.

Floor Plan Folders are now available — for complete information, consult the ASM representative nearest to you, or write direct.

NEW YORK — OXford 7-2667
CLEVELAND — JOrdan 4-2271 (Novelty, Ohio)
CHICAGO — WAbash 2-7822

Steel, the sinew that binds the strength of America, will serve as a magnetic attraction to call attention to **every** area of metals technology, ferrous and nonferrous, at the most metallic of all Metal Shows — the 1960 Philadelphia Metal Show, now blue-printed and ready to grow into its full dimensions. This new emphasis on the essential metals of industry reflects a growing specialization . . . a **focusing** of attention . . . to yield a greater benefit. In the evolution of the Metal Show, the time for such refinement has come. Now it is possible to achieve a concentration on **materials** that is unsurpassed anywhere for an intensive person-to-person interchange of information. The STEEL ARENA is the threshold to a whole new world of metals within the exhibits and technical sessions. The pre-eminence of a Metal Show of these dimensions is worth your closest consideration as an exhibitor — you are invited to share its benefit in any of the eleven areas of metals listed.

MAKE PLANS NOW
TO EXHIBIT AT THIS GREATEST OF ALL METAL SHOWS!

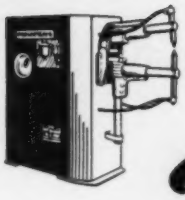
AMERICAN SOCIETY FOR METALS
Metals Park • Novelty, Ohio

. . . a benefit to every exhibitor

METAL SHOW

Theme Symbol . . . towering above the colorful, idea-full STEEL ARENA, an exciting presentation that will radiate its effect throughout the exposition halls to provide a spectacular showcase for **all** metals and their related processes and products.

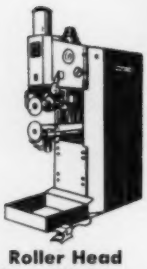
This advertisement is currently appearing in IRON AGE, STEEL, METAL PROGRESS and SALES MANAGEMENT



Standard Rocker Arm Welders

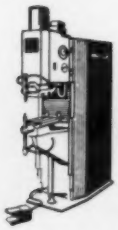
Resistance Welding

- PORTABLE WELDING GUNS—air and hydraulic
- AUTOMATIC MULTISPOT WELDERS
- AUTOMATIC ARC WELDING FIXTURES
- ASSEMBLY AND WELDING FIXTURES
- SPECIALLY DESIGNED WELDERS AND MACHINES
- THREE-PHASE WELDERS



Roller Head Seam Welders

Motor and Hydraulic Operated Flash Welder

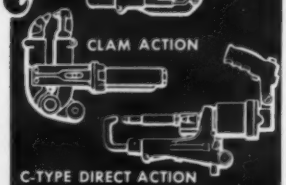


Std. Roller Head Press Type Spot and Projection Welders

STANDARDIZED GUNS

SCISSORS ACTION

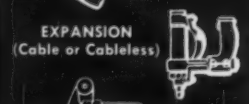
CLAM ACTION



C-TYPE DIRECT ACTION

PUSH (Solid or Spring Loaded)

EXPANSION (Cable or Cableless)



BELL CRANK ACTION

DEEP THROAT ROCKER ARM (Hydraulic only)

Guns have interchangeable standardized jaw extensions

PROGRESSIVE WELDER & MACHINE CO.

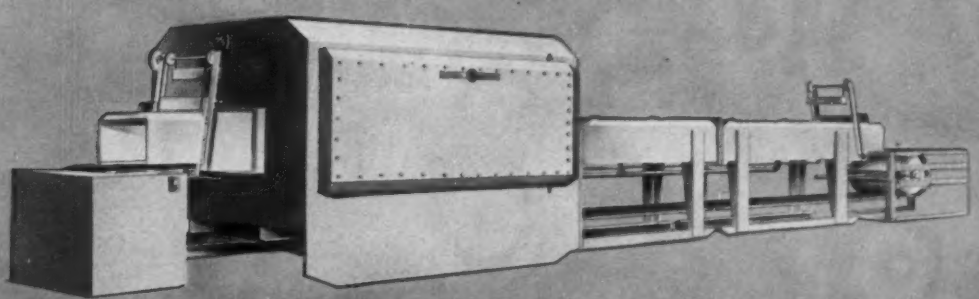
IT PAYS TO WELD

915 OAKLAND, PONTIAC, MICHIGAN RESISTANCE WELDING EQUIPMENT

Circle 507 on Page 48-B

HEAT

from General Electric



for copper brazing, silver brazing, sintering, bright annealing

Mesh-belt Furnaces from General Electric are specially designed for low-cost, high-volume production. They can be installed in a continuous production line, accepting parts ready for heat processing and delivering the processed parts ready for assembling or packaging. Available with either ribbon or silicon carbide resistors, the furnaces provide reliable, continuous operation with minimum maintenance. Heavy insulation keeps operating costs down and eases working conditions around the furnace. Since these furnaces can achieve substantial cost reductions and quality improvements, they are extremely popular; over 200 General Electric mesh-belt furnaces are now in operation.

Ask your General Electric sales engineer for complete data on G-E mesh-belt furnaces or write for bulletin GED-3881. General Electric Company, Schenectady 5, New York. 756-01

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle 508 on Page 48-B

Universal Engineer Tractor

(Steel bulldozer that flies)

"What we want is an earthmover that can do the work of conventional scrapers, dozers, and tractors . . . but which weighs only half as much . . . can be parachuted into a combat area, or flown in by helicopter!"

Army ballastable all-purpose tractor, manufactured for Barnes & Reinecke, Inc., by Hendrickson Manufacturing Company, Lyons, Illinois, is built light enough to be transported by air through the use of USS MAN-TEN High-Strength Steel and USS "T-1" Constructional Alloy Steel.

That was the demand made of the U. S. Army Engineer Center, Ft. Belvoir, Va. It was fulfilled through ingenious design using welded USS MAN-TEN High-Strength Steel and super-strength USS "T-1" Constructional Alloy Steel.

The ballastable all-purpose tractor weighs approximately 16,000 lbs. empty; 32,000 lbs. loaded. The weight reduction problem was solved by designers from Barnes & Reinecke, Inc., Chicago engineers. They designed the tractor in three sections—front end, scraper bowl and rear end.

The scraper's yoke, bowl frame, apron ejector, bowl skin and drawbar were welded from 3,370 pounds of "T-1" Steel, which has a minimum yield strength of 100,000 psi. Maximum working stresses on these parts were designed to 60,000 psi, more than triple the working stress that would be used with carbon steel. This permitted maximum weight reduction while retaining strength.

By using USS MAN-TEN High-Strength Steel in the dozer blade and rear-axle housing, they obtained the necessary strength with a reduction in plate thickness from the usual ½" and 1" down to ⅛" and ¼". USS MAN-TEN steel parts totaling 1,350 pounds were designed to a maximum weight reduction while retaining strength.

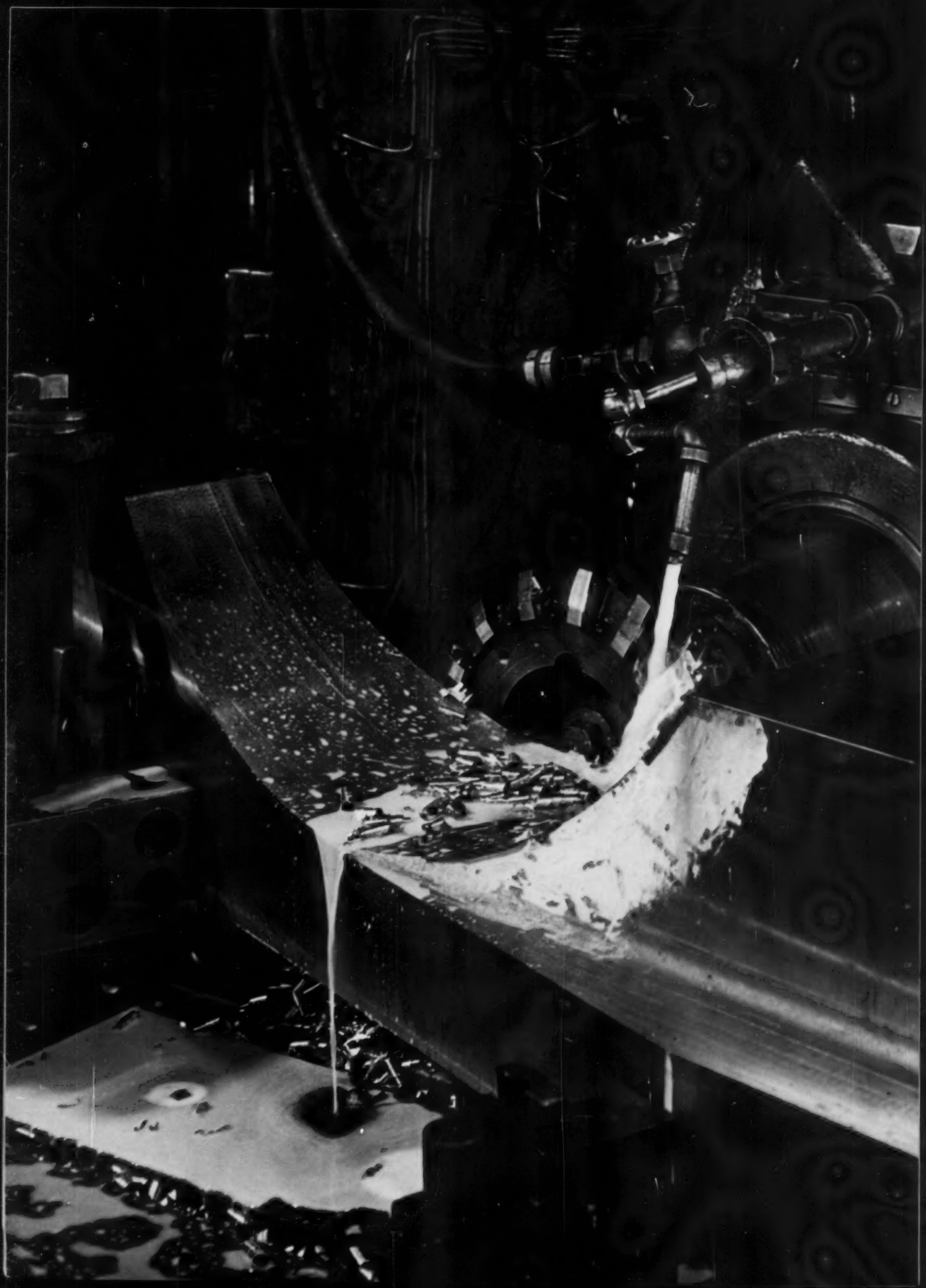
The machine shown, a feasibility prototype weighing 8 tons, will be superseded by a 10½-ton production unit powered by a diesel engine instead of an aircraft-type engine. This new item is designed to be conventionally transported by air, and it can be air dropped.

For other military vehicles, United States Steel makes extremely tough, rolled alloy steel armor plate in addition to a complete line of high-strength steels, stainless steels and carbon steels. For more information, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS, MAN-TEN and "T-1" are registered trademarks

United States Steel Corporation—Pittsburgh
Columbia-Geneva Steel—San Francisco
National Tube—Pittsburgh
Tennessee Coal & Iron—Fairfield, Alabama
United States Steel Supply—Steel Service Centers
United States Steel Export Company
United States Steel

USS



This forging may cradle the greatest source of energy on earth

One of the great scientific investigations of all time is now in progress, as we strive for a controlled *fusion* reaction. If we succeed, man will be able to generate a limitless amount of energy using deuterium fuel, a hydrogen isotope, available in inexhaustible quantities from the sea.

Princeton University carries on the study with their Stellarator-type experimental devices. The Model-C Stellarator Facility now nearing completion will cost $35 million and consists of an 8-inch-diameter, 40-foot-long, racetrack-shaped tube to control the reaction. Required ignition temperature is in the order of 100 *million* degrees. Any solid material will evaporate at that temperature, so the hot ionized gas will be confined in a magnetic field of *50,000* gauss in the Model-C Stellarator. The equipment is supported by USS Quality Forgings of Type 305 Stainless Steel.

Altogether, U. S. Steel supplied 17 of these stainless steel forgings, fully annealed, to Allis-Chalmers Manufacturing Company, major contractor for the new Model-C Stellarator.

The steel for the forgings was forged, heat-treated and machined at U. S. Steel's Homestead Plant. Each forging measures 60¼" long, 21¼" wide at the base, 15⅝" high and weighs about 2,450 pounds rough machined.

United States Steel makes many forgings for the nuclear industry. Here, a team of *experts* supervises and *controls every step* of forging production. This same team can handle your forging requirements. If you would like additional information about USS Quality Forgings, write to United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS is a registered trademark

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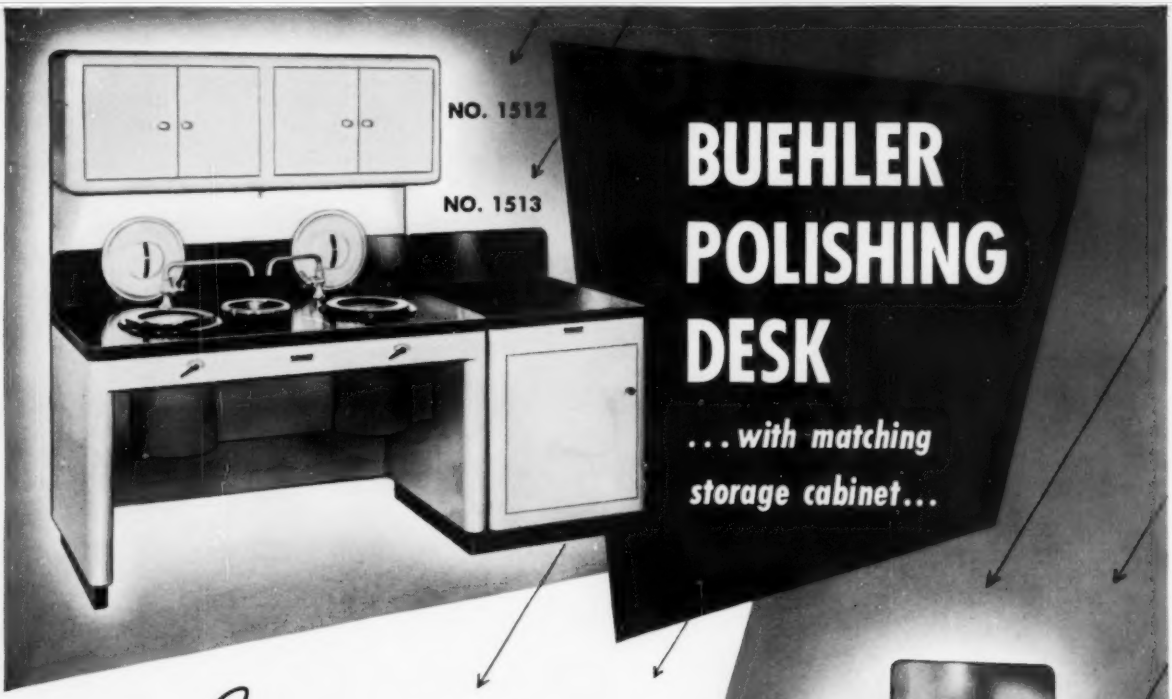


BUEHLER POLISHING DESK

. . . with matching storage cabinet . . .

For maximum efficiency in the production of specimens in the metallurgical laboratory the Buehler cabinet type polishing table with companion storage cabinets represents the latest modern development of this type of equipment.

The convenience of this streamlined polishing equipment saves time and encourages the operator to produce the highest quality of polished sample.

Item No. 1511 is a two-unit polishing table with Formica top approximately 60″ long x 27″ deep x 30″ high to table top. Two 12″ swing spouts, drain, 8″ diameter wash bowl, plumbing, and wiring.

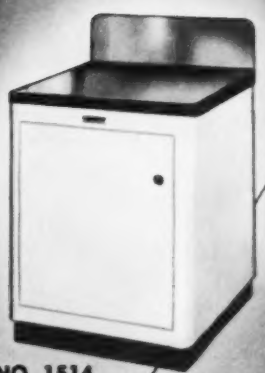
Recommended accessories to complete an efficient set up for maximum convenience are: No. 1512 storage cabinet with recessed light and No. 1513 supporting panel for installation above polishing desk. Or, No. 1514 floor model storage cabinet. Both these cabinets can be used together to advantage in most laboratories.

The Formica top and back on the table and cabinet is installed with a smooth Formica edge that eliminates all metal rims that may form pockets for water and dirt. Covers are held in place on the back by magnetic holders. The large 8″ wash bowl is a new feature that enables the operator to use both hands in washing specimens.

All metal construction finished in hammer tone grey makes a very attractive appearance.

Prompt delivery can be made on these new items.

The Buehler Line of Specimen Preparation Equipment Includes . . . Cut-Off Machines • Specimen Mount Presses • Power Grinders • Emery Paper Grinders • Hand Grinders • Belt Surfacers • Mechanical and Electro Polishers • Polishing Cloths • Polishing Abrasives



NO. 1514

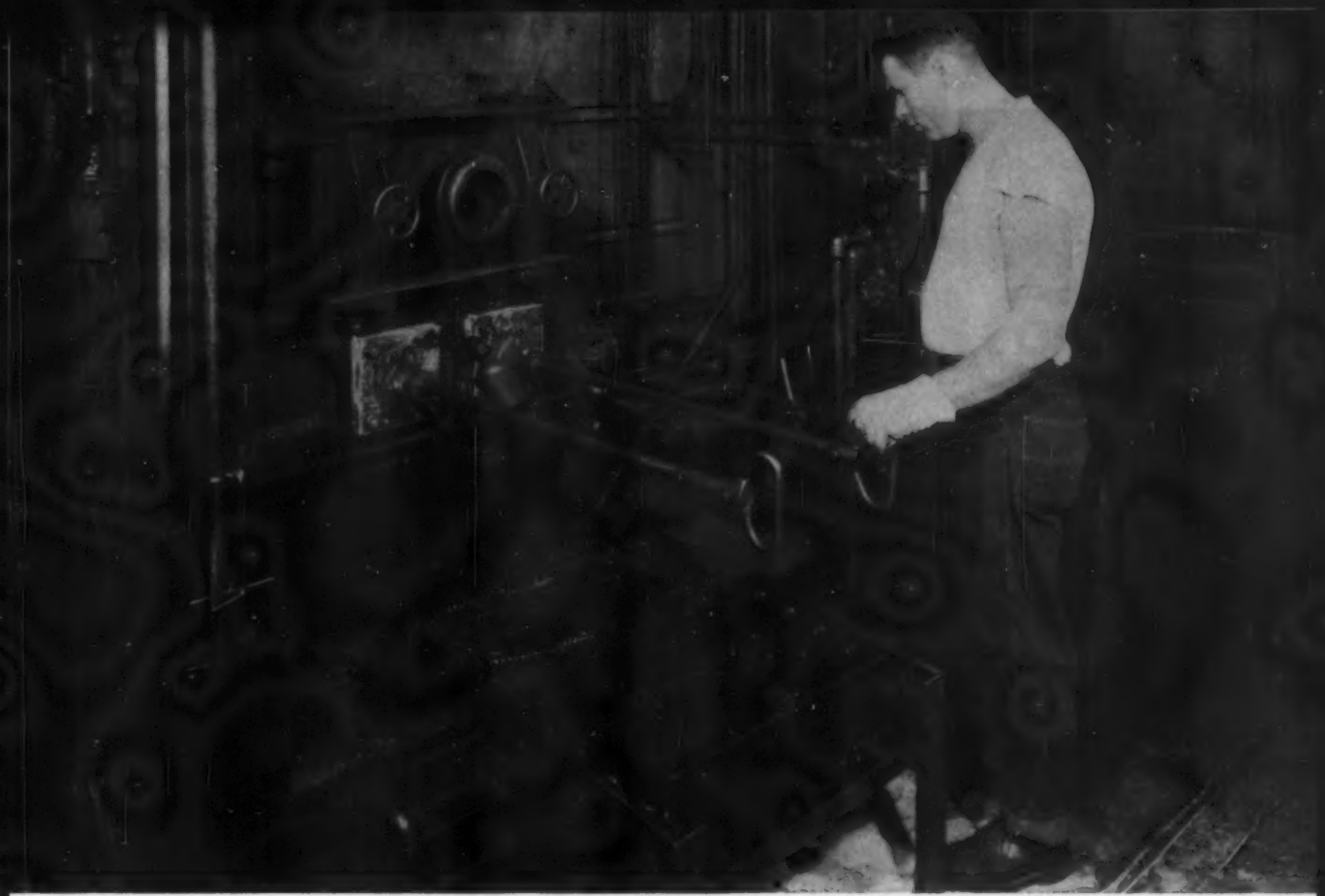
NO. 1511

Buehler Ltd.

METALLURGICAL APPARATUS

2120 GREENWOOD AVE., EVANSTON, ILL.

Circle 494 on Page 48-S



National Cash Register reports:

"Gulf Super-Quench eliminates costly straightening"

Frank G. Wymer, right, Job Foreman, Heat Treat Department, and R. H. Ball, Gulf Sales Engineer, discuss physical properties and tolerances required for National Cash Register's accounting machine parts.

"We produce 25,000 to 30,000 separate parts for our cash registers, accounting machines and computers," says C. E. Mentel, Heat Treat Foreman, National Cash Register Company, Dayton, Ohio. "All are thin-sectioned parts which must be hardened uniformly to accurate dimensions. With so many different parts to be quenched, naturally distortion must be closely controlled to avoid costly straightening."

Fortunately, distortion is not a problem at National Cash Register, and costly straightening operations after quenching are unnecessary. For 20 years NCR has built its entire heat treating program around dual action Gulf Super-Quench. "Gulf Super-Quench," says Mr. Mentel, "lets us get the hardness we need with negligible distortion. It keeps growth within predictable limits, and within quenched tolerances as low as plus .001-in., minus .000-in."

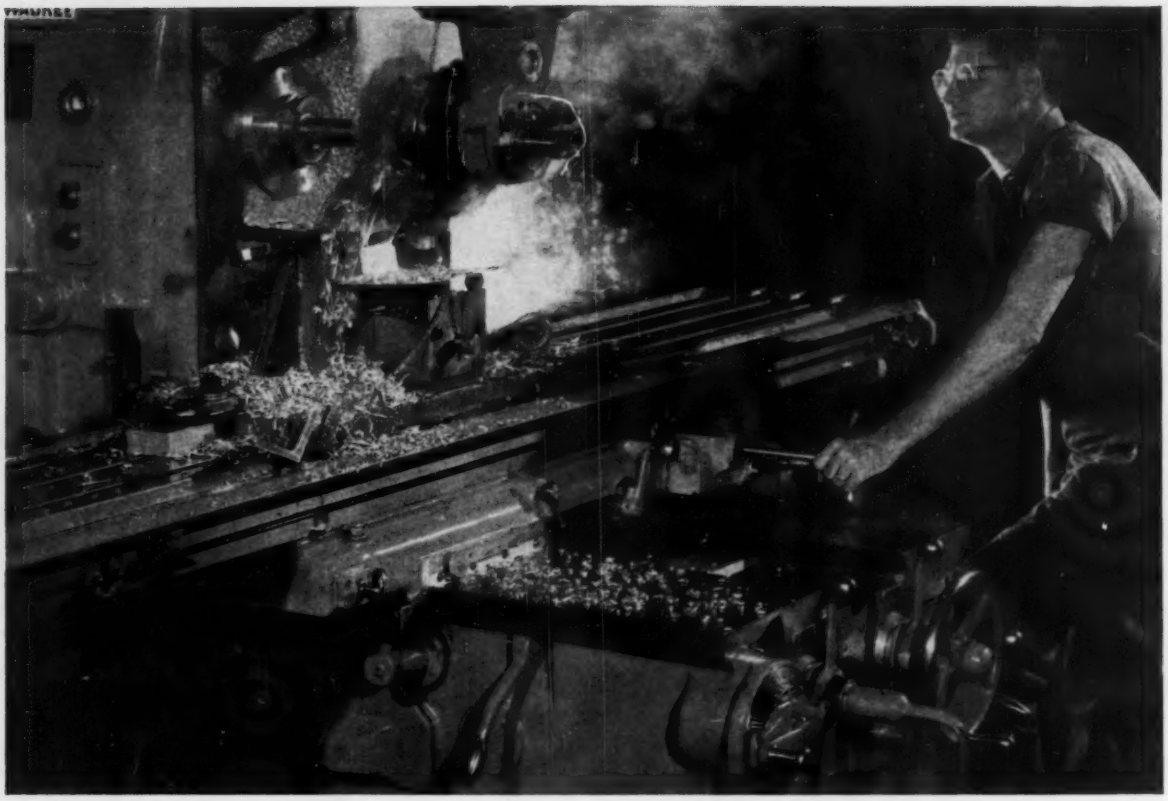
Gulf Super-Quench combines superior quenching power through the hardening range with slow cooling in the final or distortion ranges. More than likely, this quenching oil can be used profitably in your heat treat department. Write us today for comprehensive literature on Gulf Super-Quench. Or, just contact a Gulf Sales Engineer at your nearest Gulf office.

GULF OIL CORPORATION

Dept. DM, Gulf Building, Pittsburgh 30, Pa.

GULF MAKES THINGS RUN BETTER!

Circle 510 on Page 48-B



As this heavy-duty milling machine makes a high-speed cut, vital components of AISI 4340 and 4620 nickel alloy steels provide strength and wear-resistance, help maintain precision tolerances.

Two nickel alloy steels...4340 and 4620... give this machine sustained cutting accuracy

Here's how two general-purpose steels used by Kearney & Trecker in their heavy duty TF series milling machine have helped that company maintain its famous high-performance standards:

The spindle is made of AISI 4340 nickel alloy steel. This through-hardening steel is quenched and tempered to develop good fatigue strength and high tensile strength with a minimum of distortion. Spindles of 4340 steel resist torsional stresses and wear while maintaining straightness at every running speed.

Gears are precision-cut and wide-faced. They are made of AISI 4620 general-purpose carburizing steel. These gears are carburized and hardened to 58-62 Rockwell "C". What's more, AISI 4620 nickel alloy steel has a tough core to withstand shock loading.

This report is typical of the many coming in from manufacturers who have employed the two General Purpose Steels for a variety of machinery components.

Available right off the shelf from your local Steel Service Center, AISI 4340 and 4620 offer you a two-fisted way to cut costs and still satisfy the majority of your engineering requirements. Other standard nickel-containing steels – providing particular combinations of properties – are also available from your Steel Service Center for your remaining needs.

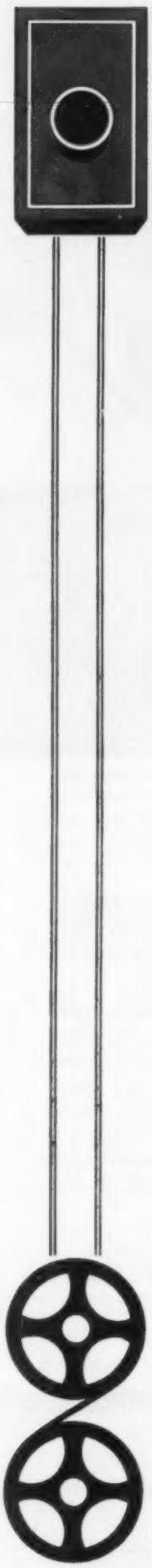
Consider nickel alloy steels for gears, shafts, bearings and other machine parts you design, order or use. And any time you require engineering information to help you select the right material for your application, write to INCO, outlining your problem. We will be glad to help.

The INTERNATIONAL NICKEL COMPANY, Inc.
67 Wall Street New York 5, N. Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Circle 511 on Page 48-8



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MP-6

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Hayes Type LAC-50M Conveyor Furnace for alloying transistors and diodes as well as other brazing work provides 3-zone heat control to obtain exact temperature curve profile required for each operation. Continuous and automatic, LAC-50M puts "push-button" brazing on a fast paying basis.

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Hayes BAC-200 series furnace for high-production stainless steel brazing.

Pioneer of controlled atmosphere heat treating, C.I. Hayes developed the *first* electric furnace for stainless steel brazing. Today, Hayes offers one of the most extensive lines of heat treating equipment for brazing; including conveyor, straight-through, vacuum, forced-convection furnaces . . . plus all types of atmosphere generators.

Hayes "know-how" also offers you *customized techniques* for brazing. Hayes engineers determine the proper selection of alloys, correct placing and fixturing of work, choice of atmosphere, and proper time-temperature cycles for the full range of metal bonding applications . . . from aluminum alloys (900°F range) to such precious metals as platinum (3400°F range). Hayes "show-how" then proves the technique, using actual production-line equipment in our laboratory.

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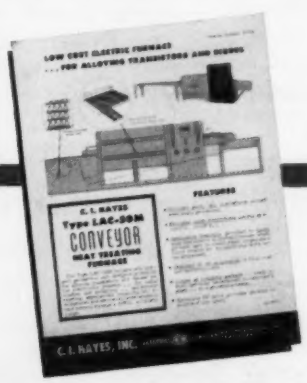

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Circle 512 on Page 48-B

225. "Practical Data for Metallurgists"

The fifth edition of this popular 76-p. booklet includes the latest metallurgical information on standard steels — their chemical compositions, mechanical properties, hardenabilities, forging temperatures, transformation temperatures, creep strength and stress-rupture characteristics, as well as weight tables and hardness conversion charts. Also included are data on special steels developed since the last publication. *Timken Roller Bearing Co.*

NEW LITERATURE

Ferrous Metals

226. Alloy Steels
Information available from *Republic Steel* on alloy steels, stainless steels, wire, and special products, such as hot rolled A8637 alloy steel for use in forged connecting rods.

227. Nickel Alloy Steels
37-p. booklet of interest to those involved in design or fabrication of machinery for the construction industry—deals with properties of materials, power components, motive units, and machinery. *International Nickel Co.*

228. High-Speed Steels
Superior machinability is claimed for *Latrobe's* "Desegatized" high-speed steels which are structurally uniform and contain no harmful carbide segregation or porosity. An even dispersion of alloy sulphides promotes better machinability.

229. Stainless-Clad Steel
"Bridge Bearing Plate Bulletin F-60" summarizes test data on corrosion-resistant, less expensive stainless-*clad* steel for a bridge bearing plate application. *Lukens Steel Co.*

230. Thermal Fatigue
Electro-Alloys Div. publishes research reports on thermal fatigue and high-alloy casting design. Most recent: "The Mechanism of Thermal Fatigue," by H. S. Avery.

231. Stainless Foil
Data sheet describes thin (0.0002 to 0.010 in.) stainless steel strip up to 25 in. wide. Type 302, 305, 316, 430, 17-7PH, PH-15-7MO, and other high temperature alloys. *Somers Brass Co., Inc.*

232. Specialty Steels
Proper steel selection will save operations and insure satisfactory performance. "Physical Property Charts" from *Wallace Barnes Steel Div.*, gives mechanical data and forming characteristics for cold rolled specialty steels.

233. Alloy Steels
"Quick Facts About Alloy Steels" from *Bethlehem Steel Co.*, deals with the basic facts about alloy steel metallurgy, including various heat treatments, microstructures, and properties.

234. PH Stainless
Corrosion resistance, ease of fabrication, and excellent mechanical properties make 17-4PH stainless steel highly economical for valve and pump parts, shafts, and fasteners operating under severe conditions. Catalog from *Armco Steel Corp.*

235. Alloy Castings
"Heat and Corrosion-Resistant Castings —Their Properties and Applications" has been published by *International Nickel Co.* Ni-Cr-Fe alloy castings provide useful strength at 1200 to 2200°F. in reducing, oxidizing, sulfur-containing, carburizing and nitriding atmospheres.

236. Precipitation Hardening
Booklet on *Allegheny Ludlum's* two precipitation - hardening stainless steels, "AM-350" and "AM-355." These alloys are easy to fabricate, have high strength-to-weight ratios, and are very corrosion resistant.

237. Publications Catalog
Crucible Steel Co. offers a publications catalog describing steel applications in: agriculture, hard surfacing, magnets, springs, tools, tubing, drills, vaults, plus several general publications, titanium products, and vacuum-melted alloys.

238. Cold Finished Bars
New folder has been issued by *Bliss & Laughlin* detailing the advantages realized in production of parts from bars of superior "Lusterized Finish."

239. Extruded Steel
Standard design guide points out important factors in designing steel and stainless shapes to be produced by extruding using the patented Ugine-Sejournet process. Standard tolerances and specifications on a wide range of alloys, as well as a glossary of extruded-shape terms. *H. M. Harper Co.*

Nonferrous Metals

240. Aluminum Extrusions
Flyer discusses aluminum extrusions for use in peacetime atomic energy. Tube plates were extruded by *Precision Extrusions, Inc.* for Argonne National Laboratory; an aluminum-nickel alloy, M-388, was specified.

241. Columbium Alloys
Bulletin CBA3-P7 suggests possible nuclear applications for two columbium-base alloys: "Cb-22" containing Al and V and "Cb-65" containing Ti and Zr. These alloys have higher strength and better oxidation resistance than Cb, while maintaining the same low neutron-capture cross-section values. *Union Carbide Metals Co.*

242. Lithium
An independent, unbiased paper, "Lithium, A Promising Alloying Element," summarizes the alloying potential of lithium with a number of metallic elements, and reviews alloy systems already developed. *Lithium Corp. of America.*

243. Rare Earths
Bulletin on rare earths and yttrium metal is offered by *Lindsay Chemical Co.* These metals are available in experimental quantities in a wide range of purity. Forms offered: ingots, lumps, or turnings.

244. Aluminum Extrusions
Substantial weight savings are possible with B51S aluminum extrusions for high-voltage transmission towers. Transportation and installation are easier, and maintenance is reduced. *Aluminum Ltd.*

245. Cu-base Alloys
Which is the most economical form of production for your design? Sand castings —centrifugal castings—extrusions—shell-mold castings—rolled sheet and plate—fabrications. One-source service provides finished parts to your specifications. *Ampco Metal, Inc.*

246. Tungsten and Molybdenum
Isostatic pressing and sintering can produce 10 in. diameter ingots, 4 ft. long in tungsten and molybdenum alloys. Fine grain size allows direct reduction by forging, rolling, or extruding. *Sylvania Electric Products, Inc.*

247. Precious-Metal Cladding
6-p. brochure surveys uses of gold, silver, and platinum-group metals in solid, clad and cored forms. Sizes, shapes, and alloy compositions are listed. *Metals and Controls Div.*

To request any item listed, circle number on Reply Card, p. 48-B

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Circle 513 on Page 49-B

248. Production Facilities

Facilities for producing sheet, plate and extrusions, as well as sand, permanent mold, and die castings in magnesium and aluminum alloys are presented in 12-p. booklet from *Dow Metal Products Co.*

249. Tungsten Alloys

Properties, fabrication methods, sizes and shapes of *Kennametal* heavy tungsten alloys presented in 8-p. bulletin. Applications: radioactive shielding, balancing, and high inertia rotational control.

250. Rare-Earth Elements

Vitro Chemical Co. has issued an 8-p. technical report containing data on properties and analyses for thorium, scandium, yttrium, and 11 rare-earth elements and alloys for use in missile development, ceramics, and atomic energy.

251. Aluminum Castings

Pressure-tight aluminum castings produced with "Asarco" process. Shrinkage is reduced, yield is increased, and a brighter, cleaner surface is obtained. *Federated Metals Div.*

252. Aluminum Pig

Information on a redesigned 50 lb. aluminum pig with an interlocking notch that holds them in place when stacked (44 pigs make a 2200-lb. bundle). *Alcoa.*

Heat and Corrosion Resistant Materials

253. Graphite Powder

Southwestern Graphite Co. offers "Microcrystal" graphite for additions to copper, bronze, or iron powders. Data sheet and free test samples of graphite powder available.

254. "Haynes" Alloys

A furnace tray of "Hastelloy X" withstood operations at 1450 to 2040°F. for three years. Alloys for heat, corrosion, and wear resistance are available as castings, forgings, sheet, bars, or fabricated parts. *Haynes Stellite Co.*

255. Hardfacing

"Econoseat" process for applying heat and corrosion resistant coatings to valve faces reduces amount of protective alloy required. The process can be applied to many parts, other than valves, requiring a protective surface. *Eaton Mfg. Co.*

256. Graphite Piping

Bulletin 965-2 provides detailed dimensions on graphite fittings and pipe. Armored pipe—sheathed in woven glass fabric—is furnished in diameters from 1 to 8 in. with standard ASA flanges. Standard pipe is available in sizes from 1 to 10 in. O.D. *Falls Industries, Inc.*

257. Superalloys

Information on "Super 3 and 6," cast Cr-Co-W abrasion-resistant alloys with a 40% lower price advantage, and 17-4PH stainless castings, with better guaranteed properties. *WaiMet Alloys Co.*

258. Graphite

Informative brochure outlines uses, manufacture, and properties of graphite. Easily machined, high thermal and electrical conductivity, high temperature dimensional stability, and chemically inert. *Great Lakes Carbon Corp.*

259. Filter Crucibles

"Micro-Porous" porcelain filter crucibles require no extra preparation and eliminate disc dissolving, weight change during ignition, and filtrate contamination with asbestos particles. Bulletin SC-1051, *Selas Corp. of America*

260. Carbon and Graphite

For handling molten iron, carbon and graphite refractory blocks, bricks, and tubes are recommended. They resist slag and thermal shock, are not wet by molten iron, have low thermal expansion, and increase in strength with an increase in temperature. *National Carbon Co.*

Tool Materials

262. Colloidal Graphite

Dispersions can be used in forging compounds, as high temperature lubricants, in extrusion die lubricants, and as parting agents. *Graphite Products Corp.* offers literature and working samples.

263. Cold Drawing

The *Vaughn Machinery Co.* "Motomatic" affords automatic production of straight, cut lengths direct from the coil, while reducing scrap to a minimum.

264. Drop Forging

The advantages of automatic closed die forging results in more efficient production and a lower-cost product. Booklet and motion picture studies offered by *Chambersburg Engineering Co.*

265. Radial Drew Forming

Forms shapes by "stretch relieving" and reduces rejects appreciably. Plant facilities folder describes this machine as well as other high-speed production forming equipment. *The Cyril Bath Co.*

266. "Dag" Dispersions

Acheson Colloids Co. reports on uses for colloidal graphite via their "Dispersions Digest." Switching to "Aquadag" realized a 30% savings in material handling costs for an aluminum extruder.

267. Saw Blades

36-p. sawblade handbook and catalogue also discusses cutting problems frequently encountered. *Ladish Co.*

268. Wire-Cutting Machine

Details available from *Mettler Machine Tool, Inc.* about high-speed "unitized" wire straightening and cutting machines handling stock up to 11/16 in. diameter.

269. Hot Work Steel

"UHB Calmax" hot work toolsteel has superior hot hardness, compared to 9% or 5% tungsten toolsteels. The steel resists heat checking and wear in hot pressing, die casting, and extrusion operations. *Uddeholm Co. of America*

270. "E.P." Lubricant

Bulletin 46 on "Fleximet PCM" metallic-base lubricant, fortified with extreme pressure (E.P.) additives to provide improved lubricity plus a heat resistant protective film. *Swift & Co.*

271. Mist Coolant

A self-contained mist coolant unit for cutting, sawing, grinding, milling, turning, boring, and tapping operations is offered by *Bijur Lubricating Corp.* End-point atomizing prevents condensation in the tube, produces efficient cooling without sputter or drip.

272. Vertical Band Saw

Fast, economical, heavy-duty band sawing explained in 8-p. catalog. Applications include: shanking die blocks, sectioning castings, and slicing large billets. *DoALL Co.*

273. Vibrating Mill

Allis-Chalmers Mfg. Co. has introduced a 30-in. vibrating mill which can outproduce a tumbling mill 15 to 30 times per unit volume. Initial cost is at least one-third lower than any other machine of comparable capacity.

274. Explosive Forming

Bulletin from *Propellex Chemical Div.* outlines advantages of explosive forming.

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a vacuum pump as dynamically balanced as . . .

Engineered to give you years of vibration-free, superior operation, Stokes Series H Microvac pumps are the most advanced in their class. Exceptionally compact, Stokes pumps take up 50% less floor space than conventional vacuum pumps.

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Circle 514 on Page 48-B

FOR SHEER, SHEAR STRENGTH

Hydraulic Pressure tests on Bridgeport Brass Company's patented cladding system show perfect no-leak bonds over 3000 psi.

...*Bridgeport Brass Uses EASY-FLO 45 to Bond Their Clad Metals*

The "thick and thin" of cladding—from .010 to 2¾" in a combination of ferrous and non ferrous metals—calls for a bonding agent that will hold under the most severe forming and service operations. The answer, in every respect, is Handy and Harman's silver brazing alloy, EASY-FLO 45.

The uses to which these clad metals are put range from the kitchen to power plants, refineries, chemical and food-processing installations. Famous Bridgeport Copperware, used by housewives throughout the country, is made from a triple-clad metal consisting of a sandwich of two sheets of .010 stainless steel bonded to both sides of a sheet of .025 copper. The metals are joined in Bridgeport's patented process at *finish gauge*. So strong is the bond that no difficulty is encountered in the forming operations which follow.

Tube sheets, though their uses are far from "domestic," require the same "bondability." Tests at Bridgeport show that shear strength exceeds 20,000 psi. And this involves the cladding of carbon steel to as many different metals as stainless, brass, Monel and copper.

The primary need here, of course, is strength. EASY-FLO 45 has other attributes that are more than welcome under *any* metals-joining conditions: thermal and electrical conductivity, gas- and liquid-tightness, ductility, ease of application and economy are some more that we'd like you to know more about. We are ready indeed to further acquaint you with the significant benefits of silver alloy brazing by sending you our Bulletin 20, which is a clear and comprehensive introduction to one of the simplest, *saving* metals-joining methods in existence. Handy & Harman, 82 Fulton Street, New York City 38.

Your No. 1 Source of Supply and Authority on Brazing Alloys

HANDY & HARMAN

General Offices: 82 Fulton Street, New York 38, New York

Circle 515 on Page 48-B

It can shape difficult-to-form materials and can form complex shapes in one operation. It can reduce tooling costs, hold tight tolerances, and reduce scrap losses.

Industrial Heating

275. Gas Burners

Catalog from *Chas. A. Hones, Inc.* presents line of "Buzzer" burners and furnaces for heat treating, melting, and soldering, including high-speed, full muffle furnace for temperatures to 2400°F.

276. Sintering Furnace

20-p. Bulletin 591 illustrates many different types of furnaces and applications for each, including a sintering furnace for processing metal powder products and bonding metal powder to strip. *Electric Furnace Co.*

277. Combustion Tubes

Information from *McDanel Refractory Porcelain Co.* on gas-tight combustion tubes for accurate analysis. Uniform, thermal shock-resistant mullite or "Zirco" ceramics for service to 3000°F.

278. Induction Heating Units

Induction heating is a practical and efficient source of heat. For example, induction heating for the intermediate annealing of strip can be done in-line between two cold working operations. *Lepel High Frequency Laboratories.*

279. Carburizing Compound

"Non-Burning" carburizing compound is economical to use, has good uniformity and low replenishment requirements, and does not burn after removal from the furnace. It is especially suited to alloy gear carburizing, which involves a direct quench. *Park Chemical Co.*

280. Heat Exchanger

Improve heat treating results by controlling quenching bath temperature. "Aero" heat exchanger transfers heat, at input rate, to the atmosphere. Flashing is prevented and production and quality is improved. *Niagara Blower Co.*

281. Shaker Hearth

Information on *American Gas Furnace Co.* "Automotion" furnaces, which operate automatically and continuously. Rotary retort or shaker hearths both deliver maximum efficiency and economy for any heat treating process.

282. Wire Cloth

130-p. reference manual on wire cloth, metal-mesh conveyer belts, and other wire cloth fabrications. Belts can be made heatproof, coldproof, corrosion resistant, and in any mesh, weave, or alloy. *Cambridge Wire Cloth Co.*

283. Furnace Tubes

All-sheet construction increases furnace tube life up to 100% by minimizing burnout. Smooth walls result in uniform gas flow and reduce carbon build-up. Catalog includes size, shape, and alloy data for radiant tubes. *Pressed Steel Co.*

284. Thermocouples

Catalog and Price List G100-4 contains information on "MegipaK" mineral-insulated thermocouples. Careful quality control at *Honeywell* produces a dependable, accurate product, which is more economical in the long run.

285. Melting Furnace

Double-chamber, dry-hearth furnace melts 100 lb. of aluminum per hr., 16 hr. a day, 7 days a week. Maximum capacity is 200 lb. per hr. The furnace occupies little space and maintains critical bath temperatures during charging. Bulletin 593. *Hevi-Duty Electric Co.*

286. Induction Melting

Inductotherm engineering and service is planned to fit induction melting to your needs. Packaged controls, integral power, and design innovations, such as tilting furnace power-feed via trunnions, are examples contained in Bulletin 70.

287. Temperature Recorder

Catalog 08-101-A gives complete information on *Weston Instruments Div.* recorders and other instruments. "Model 6702" multipoint recorder handles up to 24 points with easy interchangeability and accuracy within 0.25% of span.

288. Vertical Tube Furnace

Incorporating "Kanthal" heating elements, "Model MTKS-312" vertical tube furnace is designed for precise, control of temperatures to 1600°C. A 12 in. long hot zone is provided. *Pereny Equipment.*

289. Tank Mixers

How do you get uniform hardness in a cast steel gear weighing 7½ tons? "Lightnin" mixers provide uniform turbulence in quench tank, which rapidly wipes vapor film from entire surface of gear for maximum liquid contact. *Mixing Equipment Co., Inc.*

290. Heat Treating Ovens

Bulletin No. 157 describes complete line of heat treating ovens, designed and built for individual product and process requirements. Batch and conveyer-type furnaces for operations up to 1000°F. *Young Brothers Co.*

291. Gas Atmospheres

Flyer discusses packaged gas generation systems for CO_2, nitrogen, hydrogen, reducing, and the inert gases. Compactness, trouble-free maintenance, and reliable performance are features of this equipment and the service provided by *Gas Atmospheres, Inc.*

292. Salt Bath

Facts on high-speed salt bath operations presented in brochure from *Ajax Electric Co.* Uniform, straighter work, free of decarburization, is hardened two to three times faster and at lower cost.

293. Expendable Thermocouples

Englehard Industries, Inc. discusses advantages of expendable immersion thermocouple in measuring molten steel temperatures. Positive performance and accuracy, as well as speed, economy, convenience, and safety are claimed for the replaceable units.

294. Quenching Oils

Comprehensive literature from *Gulf Oil Co.* reports on "Super-Quench" oil that can be used for both fast and slow quenching. Rasp blades need fast quenching in hardening range and slow cooling in final range—during carbonitriding operation.

295. Gantry Furnace

Catalog describes standard and specially designed furnaces, including gantry furnace (to 2000°F.) which glides over two draw furnaces, an oil quench tank, and an atmosphere tank. Operation is automatic, and either endothermic or exothermic gases may be used. *Pacific Scientific Co.*

296. Signalling Controller

Catalog 51 from *Thermo Electric Co., Inc.* describes a controller assembly in a slide-out chassis taking only 56 sq.in. of space on a panel. Red and green signal lights.

297. Dewpoint Control

"Dewtronik" and "Carbotronik" equipment for regulating the carbon potential of furnace atmospheres are described in Bulletin DC-58 by *Ipsen Industries.*

Circle appropriate number on Reply Card, p. 48-B

'PSC' RADIANT TUBES in
Any Design or Dimension
'Light-Weight' Heat-Treat Units for Every Use
PSC fabricated tubes furnish four substantial advantages: (1) Light-wall construction saves furnace time and fuel. (2) Return bends are of same wall thickness as tubes, promoting uniform flow of gas. (3) Smooth dense walls minimize carbon build-up and burn-out. (4) Up to 100% longer life. In any alloy, size or type, including parabolics. Also sheet-alloy heat-treating retorts and covers, boxes, baskets, fixtures, tubes, etc.
PSC
THE PRESSED STEEL CO • Wilkes-Barre, Pa.
Circle 516 on Page 48-B

Think what you can do with an open coil. Lee Wilson engineers, ever searching for better ways to anneal metal, scored an important breakthrough by devising a workable method for opening and handling large coils of steel. This has proved to be the most effective way to anneal yet discovered. But there's more—already several steel engineers have considered the open coil system the ideal station for oiling, cleaning, coating and other surface treatments in addition to annealing. Think what complete surface exposure means to your processing of sheet products, then contact Lee Wilson engineers for complete details and/or test coil arrangements.

Lee Wilson® ENGINEERING COMPANY, INC.

20205 LAKE ROAD • CLEVELAND 16, OHIO

HIGH PRODUCTION ANNEALING SYSTEMS

MAKE THE BEST METALS BETTER

Circle 517 on Page 48-B

* ORIGINATORS AND LEADING PRODUCERS OF OPEN COIL AND SINGLE STACK FURNACES

298. 5000°F. Furnace

"Pereco" tube furnace, heated by carbon-resistors, described in bulletin by *Pereny Equipment Co., Inc.*

299. Gas Furnaces

New catalog of entire line of equipment and accessories now available from *American Gas Furnace Co.*

300. Oil Burner

Vortex burner which produces a short intense flame even on residual fuel oil. Bulletin 116A by *Thermal Research & Engineering Corp.*

301. Heat Treating Units

Advantages of heat treating equipment made of sheet alloy—radiant tubes, retorts, boxes, fixtures—presented in booklet by *Pressed Steel Co.*

302. Billet Heaters

Continuous conveyor type of furnaces for heating 2500 lb. of aluminum billets to 1000°F. per hr. presented in Bulletin HT-53. *The Carl Mayer Corp.*

303. Small Box Furnace

Quick run-up to working temperature (2000°F. max.) and automatic prevention of overshoot is feature of "Stabil-Glow" furnaces. Details of construction available from *Blue M Electric Co.*

304. Metal Belts

Any operation that depends on continuous product flow—brazing, hardening, quenching, annealing, tempering, washing, sintering—can use *Ashworth Bros.* metal process belts. Technical literature available.

305. "Globar" Furnace

Harper Electric Furnace Corp. has issued bulletin describing line of modernized furnaces using "Globar" tubular elements and operating up to 3000°F. Heating chambers are 2 in. I.D. and up to 36 in. long.

306. Vacuum Furnaces

Information on vacuum units with fast gas cooling. These furnaces offer a safe and economical method for bright hardening and annealing of stainless steel, high-speed steels, toolsteels, and high-temperature alloys; also sintering and brazing. *Ipsen Industries, Inc.*

307. Pyrometer Accessories

Data from the *Bristol Co.* on pyrometer supplies—thermocouples, protection tubes, radiation-unit accessories, refractory insulators, mounting fixtures, thermocouple extension wire, switches, and ink.

Cleaning and Finishing

333. Cleaning & Burnishing

"Clepo 12-K" is a white dust-free granular compound, water soluble, which simultaneously cleans and burnishes steel, brass or copper parts while tumbling. *Frederick Gumm Chemical Co.*

334. Chromate Coating

For protection of light metal surfaces, use "Iridite"—chromate conversion coatings for nonferrous metals. The thin film formed cannot chip, flake, or peel. Technical data files from *Allied Research Products, Inc.*

335. Vapor Degreaser

36-p. bulletin explains nature of "Nialk Trichlor" and its application. More parts can be cleaned per dollar cost of cleaner. *Hooker Chemical Corp.*

336. Blast Cleaning

Facts on "Permabrasive," the pearlitic malleable blast cleaning shot. Faster cleaning action and lower cost per ton. *National Metal Abrasive Co.* also makes "Perma-Steel," a low-cost, long-lasting abrasive.

337. Chromallizing

Illustrated Bulletin PS discusses "Chromallizing," a proven process of diffusing Cr into a metal surface to provide an alloy case integral with the base metal. It can't peel or flake and it provides excellent resistance to oxidation and corrosion. *Chromalloy Corp.*

338. Surface Conditioner

To prepare aluminum for welding, painting, forming, or etching, *Oakite* has over 30 materials guaranteed to properly condition aluminum. Booklet F-8283.

339. Strip Coating

"Ross-Waldron" provides single-source responsibility for high-production strip coating lines for aluminum and steel. Bulletin RW-500 from *Midland-Ross Corp.*

340. Trichlorethylene

Bulletin 44A and Data Sheet 814 provide information on "Nialk MD Grade" trichlorethylene. A neutral stabilizer protects against heat, air, light, moisture, acids, and active metals. *Hooker Chemical.*

341. Metal Abrasives

"Malleabrasive" shot or grit is formulated to fit the requirements of your particular product, cleaning equipment, and operating conditions. This produces maximum cleaning efficiency and lowers blast-cleaning costs. *Globe Steel Abrasive Co.*

342. Metal Finishing

Bulletin from *Despatch Oven Co.* on engineered systems for modern finishing of metals. Features are: better rust-proofing and paint application, and more economical use of finishing materials and direct labor.

343. Preplated Metals

"Nickeloid" metals require no cleaning, no plating, and no polishing. Available in a variety of finishes and patterns on steel, copper, brass, aluminum, and zinc. Introductory kit includes metal samples. *American Nickeloid Co.*

Welding and Joining

353. Precision Soldering

Is 7 times faster with *Tocco* induction heating. Booklet describes induction brazing and soldering applications and outlines advantages of the process.

354. Brazing Furnace

Harper electric furnaces for dry hydrogen brazing of stainless steel parts are reliable and safe, due to "fail-safe" operating principle. Booklet tells how to braze stainless steel.

355. Brazing Alloys

General Electric Co.'s vacuum-melted, wide-gap brazing alloys offer: bridging of 0.060-in. joint clearances, faster and simpler job fabrication, extreme cleanliness, and lower manufacturing cost.

356. Power Systems

Folder explains "spike power" electronic control and power system for improving product quality and lowering costs on resistance welding jobs. *Robotron Corp.*

357. Strip Heaters

Preheating of hard-to-weld alloys prevents underbead cracking and other defects. Building-block strip heater systems provide controlled preheat for weldments of almost any size and shape. *J. B. Nottingham & Co.*

358. Filler Rods

Data sheets on six NCG welding filler rods, give welding and brazing characteristics, specifications and chemical analyses. Procedures and applications for welding and brazing are also included. *National Cylinder Gas Div.*

Circle appropriate number on Reply Card, p. 48-B

Fast Accurate Sulfur ANALYSIS

PETROLEUM PRODUCTS
iron steel
ORGANIC CHEMICALS
WOOD COAL
stainless alloys
COKE MINERALS
non-ferrous metals

with a

DIETERT-DETROIT Sulfur Determinator

Extremely simple direct-reading burette. No involved measuring or computing. Provides fast accurate analysis of sulfur content in scores of materials. Low cost, durable, easily maintained. Widely used in company laboratories and institutions of every description.

Dietert-Detroit Sulfur Determinator No. 3104, with combustion Furnace.

SEND FOR FREE CATALOG!

16 page Dietert-Detroit Catalog illustrates and describes both Sulfur and Carbon Determinators and complete line of accessory equipment and supplies.

HARRY W. DIETERT CO.
CONTROL EQUIPMENT
9330 ROSELAWN DETROIT 4, MICHIGAN

Send me your Carbon-Sulfur Determinator catalog.

NAME_____

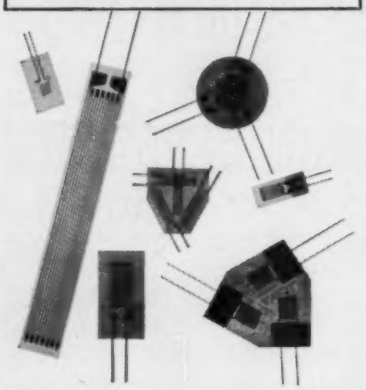
COMPANY_____

ADDRESS_____

CITY_____ STATE_____

Circle 518 on Page 48-B

The bonded strain gage makes the difference



SR-4® Transducers and Systems (see opposite page) are used wherever accurate measurement and control of weight, thrust, pressure or torque are required.

Their growing importance on the industrial and military scene is due largely to a unique combination of ruggedness and high accuracy which results from the use of a truly ideal transducer sensing element . . . the SR-4® bonded filament strain gage. This postage-stamp-size device, well known to stress analysts and structural designers as a precision laboratory tool, performs an equally important, and more permanent, function when bonded inside hermetically sealed load cells, pressure cells, and torque pickups.

There it translates minute, force-induced strains into proportional changes in a small electric current flowing through its grid. Detected and amplified, these signals are used to actuate indicators and/or recorders and to control a variety of functions and processes.

Thanks to the bonded strain gage, SR-4® transducers provide advantages unmatched by any other commercially available device.

- High accuracy (to ±0.1% or better)
- Excellent linearity and repeatability
- Rugged construction—no moving parts to wear or maintain
- Hermetically sealed—unaffected by dirt, moisture or corrosive vapor
- Consistent performance, unit to unit
- Infinite resolution
- Maximum flexibility of application and installation

SR-4® Transducers or an SR-4® System may be particularly suited to your requirements. For additional information on weight, pressure, thrust or torque measurement, write Dept. 2-G.

FIRST in force measurement

BALDWIN · LIMA · HAMILTON

Electronics & Instrumentation Division
Waltham, Mass.

SR-4® Strain Gages • Transducers • Systems

361. Selenium Rectifiers

Miller Electric Mfg. Co. has published a 12-p. technical report on selenium rectifiers, covering design, manufacture, operating characteristics, and use. A chapter on "Selenium vs. Other Rectifiers" is included.

362. Automatic Welding

8-p. brochure discusses 14 high-production, automatic, arc-welding machines, including special features for automatic operation: mechanical loading, inspection, and automatic unloading. *Taylor-Winfield.*

363. Alloys for Brazing

Speed, strength, economy, low labor costs—advantages achieved through the use of silver brazing alloys from *Handy & Harman.*

364. Caulking Loader

Flyer tells how "Model 4A" caulking loader for adhesives will save time, labor, and material when used on production and maintenance jobs. Loader can also be used for glazing compounds, sealants, putty, and mastics. *Force-Flo, Inc.*

365. Instruction Manual

Operation and use of the twin electrode, carbon arc-welding process is presented. Many applications detailed: soldering, brazing, welding, hard surfacing, braze welding, straightening, bending, and paint burning. *Arcair Co.*

Inspection and Control

371. Large Testing Machines

Cosa Corp. has bulletin describing multi-purpose machine for push-pull, bending, torsion tests; vertical and horizontal models up to 100-ton load.

372. Hardness Testers

By removing major test loads automatically, motorized "Kentrall" testers reduce operator error, increase reproducibility of test results, and raise the productive capacity of the machine—for the same price as hand-operated machines. Bulletin CRS-60. *Torsion Balance Co.*

373. Control Instruments

4-p. brochure covers line of instruments made by *Schaevitz Engineering* for measuring, indicating, recording, and controlling devices. Transducers, linear and rotary variable differential transformers, and accelerometers.

374. Ultrasonics

Booklet presents research, engineering, and production facilities of *Elion Instruments, Inc.* Custom-designed ultrasonic inspection installations, for missile and other manufacturers, are featured.

375. Testing Machines

Series of pamphlets offered by *Riehle Testing Machines* on creep and stress-rupture, fatigue, universal, torsion, hardness, and impact testing machines, as well as construction materials and wire-testing machines.

376. Microscopes

Catalog describes line of metallurgical microscopes, camera attachments, micrometers, vacuum heating stages. *Unitron Instrument Div.*

377. Thickness Gage

"UT" ultrasonic thickness gage—portable, self-powered, and direct-reading—is ideal for field use. It will measure steel thicknesses from 0.07 to 1.5 in. *Sperry Products Co.*

378. Ductility Tester

This sheet metal tester takes specimens up to 3/16 in. thick and applies up to 30,000 psi. pressure. The completely enclosed hydraulic system is directly driven by an electric motor. *Detroit Testing Machine.*

379. Hardness Testing

Catalog RT-58 gives complete details on full line of "Rockwell" hardness testers and "Brale" diamond penetrators. *Wilson Mechanical Instrument Div.*

380. Spectrometer

X-ray vacuum spectrometer for analysis of the lighter elements—below atomic number 22—permits the use of three samples at one time. Details on this and related equipment from *Radio Corp. of America*

381. Metallograph

Unitron metallograph and universal camera microscope includes all optics for 25-2000×, polarizers, filters, 3¼ by 4¼-in. camera, plus an optional vacuum heating stage for use to 1500°C. Catalog 2-D.

382. Load Indicator

Brochure describes "SelecT-o-range" dial indicator—the electronic null balance system for universal and torsion testing machines—as well as a full line of strain detecting instruments. *Tinius Olsen Testing Machine Co.*

383. pH Meters

Detailed information on comprehensive line of pH meters—ranging from the ultra-sensitive (accurate to 0.0025 pH) Beckman "Model GS" to an inexpensive pocket model. *Harshaw Scientific.*

384. Borescopes

For internal inspection of holes 0.10 in. in diam. or larger in cast, drawn, forged, or welded products. Catalog from *National Electric Instrument Div.* points out features and advantages of "Fontar" borescopes.

385. Proving Rings

Literature sets forth information on proving rings to measure tension or compression loads; capacities to 200,000 lb. Dial indicators measure deflections of 0.0001 in.; optical types detect 0.00002-in. deflections. *Steel City Testing Machines.*

386. Fatigue Testing

Information on variable speed plate machine from *Budd Instruments Div.* Specimen lengths: 2 to 24 in.; temperatures to 1800°F. Also, the rotating beam machine can test a variety of materials with great precision and at reduced cost.

387. Diffractometer

Picker X-ray Corp.'s diffraction and fluorescence analysis equipment lets you do more—easier, faster, and more accurately. You can rotate sample independently about axis, and increase or decrease take-off angle without realigning tube.

388. Electron Microscopes

Features of EM100B and EM75B models are: selective penetration to provide a choice by which adequate attenuation of the specimen is achieved, and stretching, cooling, and heating of the specimen can be done under observation. *Philips Electronic Instruments.*

389. Fused Quartz

Data on high purity fused quartz for laboratory and production equipment. Products include tubing, crucibles, trays, containers, piping up to 25 in. diam., ingots and plates. *Amersil Quartz Div.*

390. Oscillograph

36-p. manual provides detailed reports on "Visicorder" applications, such as obtaining high-frequency analog data on phase-shift heat for resistance welders, missile component and diesel engine testing, and nuclear instrumentation. *Minneapolis-Honeywell Regulator Co.*

391. "Spectrographer's News Letter"

Quarterly publication of *Bausch & Lomb Optical Co.* describes spectrographic equipment, including their "Model XIP" direct-reading X-ray industrial polychromator.

Circle appropriate number on Reply Card, p. 48-B

The bonded strain gage makes the difference

SR-4® system measures ladle additives automatically, helps turn out better ingots

A new means of adding ferro-alloys to steel automatically as it is poured from the ladle is quietly revolutionizing open-hearth steelmaking.

In developing its new Ladle-Additions Feeder, Blaw-Knox engineers turned to Baldwin-Lima-Hamilton for a rugged, accurate weighing system which would operate dependably under conditions where shock, overload and temperature change are the rule rather than the exception. The resulting system, now helping to save production time and improve steel quality in many installations, utilizes four 20,000-lb. SR-4® load cells on each additive bin. They send accurate weight signals to a B-L-H indicating and control system, which automatically feeds additive in precise amounts by weight.

In this, as well as countless other industrial applications, it is the SR-4® bonded strain gage which provides the required accuracy and dependability. Let B-L-H engineers solve your force measurement problems.

Two SR-4® load cells in adjacent bins of a Blaw-Knox Ladle-Additions Feeder. Special B-L-H system filters out vibration and shock signals, sending only precise weight data to instrument panel.

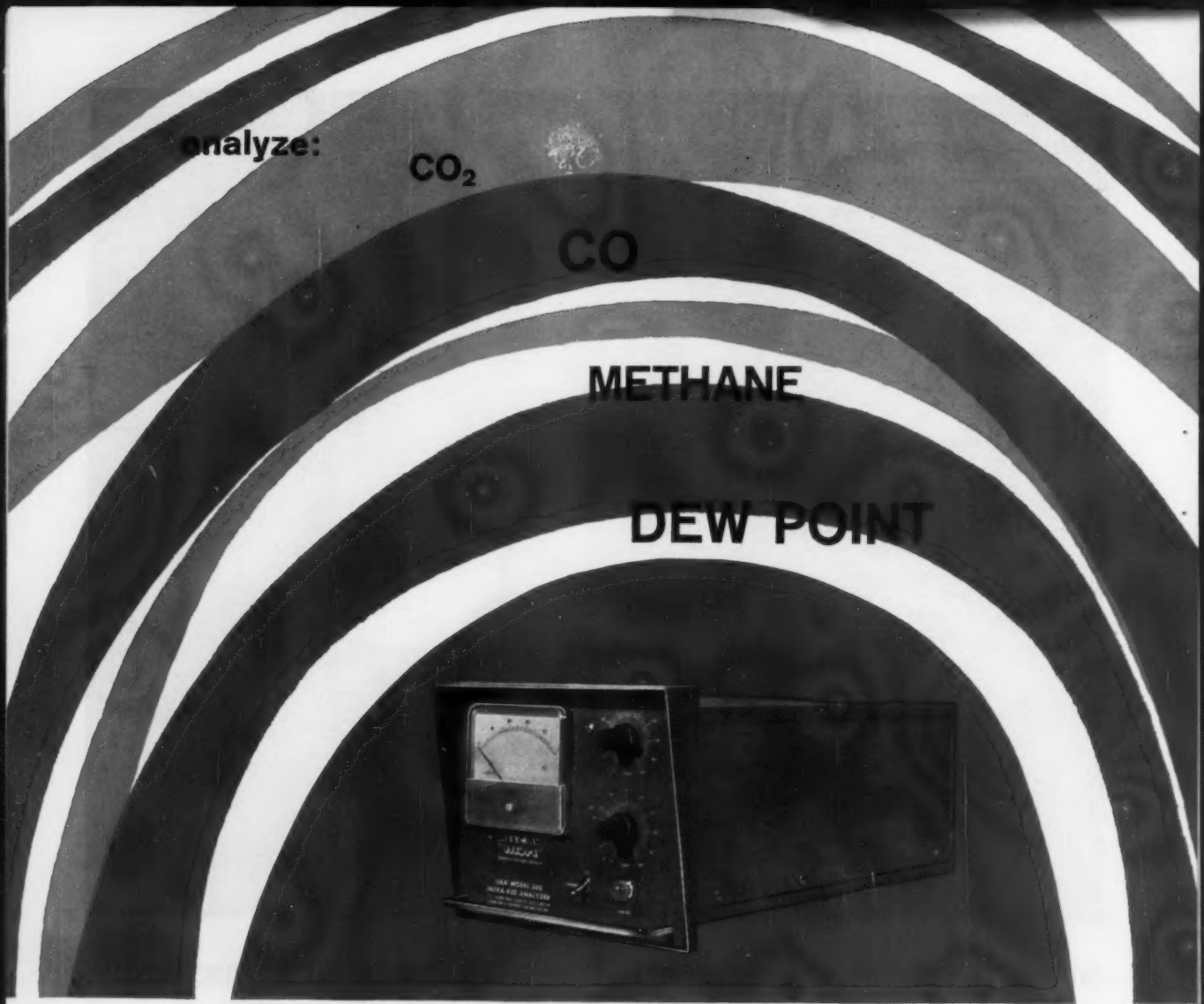
First in force measurement

BALDWIN · LIMA · HAMILTON

Electronics & Instrumentation Division • Waltham, Mass.

SR-4® Strain Gages • Transducers • Systems

Circle 519 on Page 48-S



M-S-A® LIRA® Infrared Analyzer Model 300. 9⅛" wide. 6¾" high. 18⁹⁄₁₆" long.

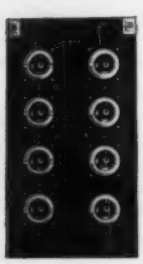
new from MSA: simplified, low-cost infrared analysis of furnace atmospheres

Here at last is a new, low-cost infrared analyzer that greatly simplifies measurement of CO, CO_2, methane and dew point.

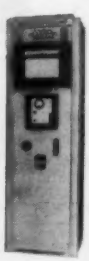
The new M-S-A® LIRA® Model 300 is *not* complex. Fact is, it's a very easy instrument to live with. As an effective check against quality control problems in furnace atmospheres, this unit is invaluable. It really helps reduce rejects.

The LIRA 300 is compact and lightweight. Entire assembly is mounted on a single roll-out tray. And if portability is desired, a handle can be added.

More information? Please state your particular problems of atmospheric analysis and control when you write for our informative new bulletin.



For Total Combustibles: M-S-A® Combustible Gas Analyzer



For Hydrogen: M-S-A® Gas Thermatron

For Oxygen: M-S-A® Oxygen Analyzer

MSA®

INSTRUMENT DIVISION

Mine Safety Appliances Company

Pittsburgh 8, Pennsylvania

Circle 520 on Page 48-B

392. High-Speed Cameras

Want to study cracking in rapidly moving metal cams, or aircraft wing tips at supersonic velocities? High-speed cameras actually "see" the problem, and thereby reduce engineering effort and development costs. *Wollensak Optical Co.*

393. Sizing and Gaging

Deltronic's 4-p. leaflet illustrates "Tenth Plug" and precision "Micro-ball" gage kits. Methods of shortcutting many tedious production and inspection jobs presented, including locating and inspecting bore holes.

394. Automatic Mill

Information on punched cards controls screwdown, roll tables, edger opening, and manipulator fingers, as well as direction of mill, entry speed, maximum running speed, acceleration rate, and provision for tandem rolling. *Datex Corp.*

Production and Casting

400. Pit Furnaces

Furnaces enclosing pressing dies for compacting billets under vacuum or controlled atmosphere and operating as high as 2000°F., illustrated in Bulletin 557 by *Hevi-Duty Electric Co.*

401. Vacuum Equipment

Stokes "Series H Microvac" pumps save up to 50% of your floor space due to compact design and they offer more pumping performance per dollar. Get handy vacuum slide-calculator.

402. Roller Leveler

Information on *Voss Engineering Co.* roller levelers, which can produce up to 150,000 lb. of flat aluminum strip per day. Unit has been in operation for 2½ yr. with no downtime.

403. Vacuum Furnace

Descriptive literature on vacuum furnaces, vacuum chambers, skull molds, crucibles, hot topping units, and ingot molds for research and production applications. *Zak Machine Works, Inc.*

404. Heat-Resistant Cement

"Lumnite" cement can be used for foundation pads, dome and wall insulation, and as lining for hot-blast mains, flues, doors, and stacks in blast furnace stoves. *Universal Atlas Cement.*

405. Vacuum Pumps

Bulletin P4-30.32 contains information on *Consolidated Vacuum Corp.* pumps and induction furnaces. The capacity is expandable from 300 to 1000 lb. in large production models.

406. Castable Linings

Refractory castable linings are used in stress-relieving furnaces, soaking pits, and furnace car tops where severe abrasion and mechanical abuse are likely to occur. Bulletin R35A, *Babcock & Wilcox.*

407. "Vacuum Micronicle"

This is the title of a periodical containing details on high vacuum equipment and applications, including a vacuum levitation furnace which has no crucible for containing molten metal. *National Research Corp.*

408. Ramming Mix

"Magnorite" fused MgO ramming mix adds life to linings and rams easily to high, uniform densities. Careful grain sizing minimizes segregation. *Norton Co.*

409. Silicon

Vanadium Corp. of America offers a complete line of silicon products. By selecting the right one for your particular application, increased efficiency and economy are realized.

410. Rare-Earth Addition

Elements which readily segregate in large rimming ingots—sulphur, carbon, phosphorus, and nitrogen—are held within close limits through the economical use of rare earths. *Molybdenum Corp.*

411. Dust Collector

Cylindrical, fabric dust collector for reclaiming dry fines have been introduced by *American Air Filter Co.* Operation and design characteristics of Model B "AMERjet" collector discussed in Bulletin 279C.

412. Compressed Gases

Matheson Co. has released a compressed gas catalog containing prices and data on 85 gases and gas mixtures, as well as gas regulating and handling equipment. Guaranteed gas analyses for mixtures to parts per million.

413. Oxygen Lances

Improved lance can withstand 300 more heats, it is claimed. New design concentrates cooling water at the critical points of the tip. *Hutton Fabricating Mfg. Corp.*

415. Tramp Iron Removal

From raw, crushed slag feed. Can be done efficiently with a "Series SE" self-cleaning magnet and conveyer belt. Catalog 752-9, *Magnetic Engineering & Mfg.*

416. Wax Patterns

"Model WP-60" wax injection press for investment casting injects wax in a "mushy" state into the die. This reduces shrinkage. Pressure and temperature are closely controlled. *Alexander Saunders and Company.*

Parts, Forms, Shapes

417. Finned Tubes

Remarkable "Flo-Rol" process can produce a wide variety of internal configurations in stainless, superalloys, and refractory metals, plus many bi-metal and tri-metal combinations. Bulletin offered by *Damascus Tube Co.*

418. Cold Drawn Bars

"Lusterized" finish removes contaminants formerly found on all cold drawn bars. This minimizes plating preparation, reduces machining, and prevents clogging of automatic machines. *Bliss & Laughlin.*

419. Toolsteel Tubing

E-52100 steel tubing can be used in ball-bearing races, nozzles, gear and pinion parts. Data Sheet 14 presents other applications where high strength and hardness, wear, abrasion, and shock resistance; and notch toughness must be considered. *Superior Tube.*

420. Tube Fittings

The *Lenz Co.* has published a comprehensive, 118-p. catalog on tube fittings, featuring specification tables, actual-size cutaway drawings, and a complete reference index to each fitting.

421. Contour Rolling

D. E. Makepeace Div. announces contour rolled stock with dimensions held to plus or minus 0.001 in. Formed stock, which does not require a final finishing operation, can be furnished.

422. Pressure Tubing

Bulletin TB-417 describes seamless pressure tubing and pipes in carbon and alloy steels. Satisfactory and economical tube performance requires matching the proper tube to the job. *Babcock & Wilcox Co.*

423. Precision Tubing

Brochure from *J. Bishop & Co.* discusses precision stainless and nickel tubing up to 1 in. O.D. for mechanical, aircraft, capillary, and hypodermic applications. Platinum products and chemicals also described.

Circle appropriate number on Reply Card, p. 48-B

Portable Pyrometer Indicator Does Many Jobs

MINIMITE®

Null Balance, Potentiometer Type

The "MiniMite" Portable Potentiometer Indicator gives you laboratory accuracy in a rugged, versatile instrument. Use it conveniently for a wide range of temperature measurement, calibration and test purposes. Its dimensions are only 4" x 5" x 6"—weight is under 4 lbs. Accuracy is ¼ of 1% of scale range.

Temperature Measurement For direct temperature measurement, connect the "MiniMite" to a thermocouple. It's ideal for laboratory work, emergency operation or substitution for instruments under repair...also for many types of research and test work.

Calibration Use the "MiniMite" with equal facility for calibrating thermocouples, or both potentiometer and millivoltmeter-type instruments.

Scale Range Individual ranges on the "MiniMite's" double-range scale are almost 24" long. Choose from 49 different range combinations to cover temperatures from −300°F. to +3200°F. for all standard thermocouples, and millivolts from −6.2 to +62.

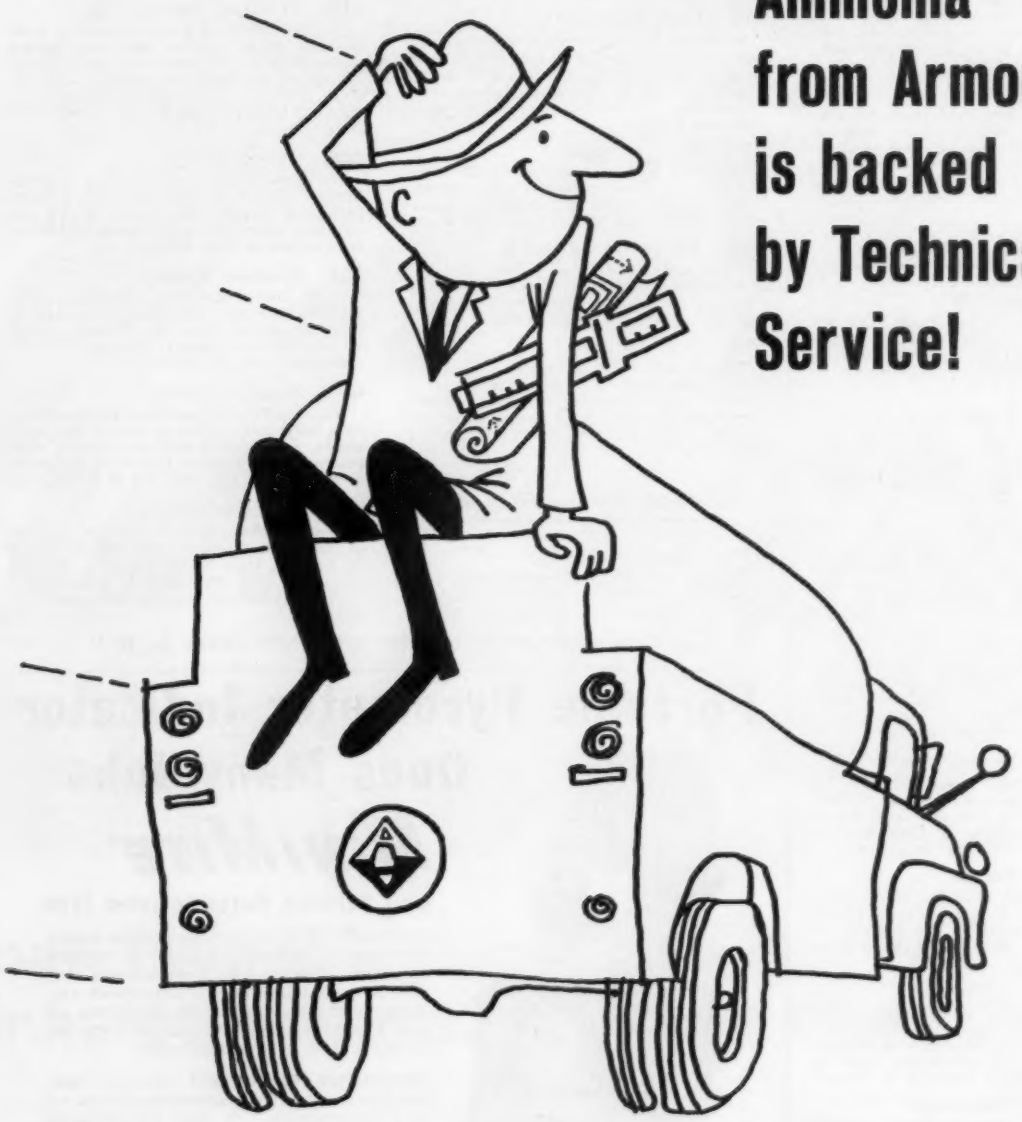
Write For Bulletin 64-16

Thermo Electric CO., INC.
SADDLE BROOK, NEW JERSEY

In Canada:
THERMO ELECTRIC (Canada) LTD.,
Brampton, Ont.

Circle 521 on Page 48-B

Ammonia from Armour is backed by Technical Service!



When you buy Armour high-purity anhydrous ammonia you're assured of expert technical service, based on 69 years of experience with ammonia—its control, storage and uses.

Blueprints, equipment lists and on-the-job supervision of ammonia equipment installations are some of the basic services Armour offers.

Armour's technical service men can help you set up storage facilities, safety procedures—even aid in improving your heat treating operations. Why don't you take advantage of this experience and service from Armour?—a leader in the development of ammonia-derived atmospheres for heat treating.

Be trouble-free . . . buy Armour Ammonia—*at least 99.98% pure when delivered* and backed by technical service whenever you need it, at no extra cost.

Ammonia Sales

Armour Industrial Chemical Company

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Circle 509 on Page 48-B

The American Society for Metals and Metal Progress serve 32,000 member-readers in 11 major areas of the metals industry.

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS: Alloy, Carbon, Free Machining, Stainless Steels, Hot and Cold Finished Bars.

NONFERROUS METALS: Aluminum, Beryllium, Brass, Bronze, Columbium, Copper, Lead, Magnesium, Molybdenum, Monel, Nickel, Rare Earths, Tantalum, Titanium, Tungsten, Zinc, Zirconium.

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS: Special Alloys; Carbon, Graphite; Ceramics, Cermets, Thermal Insulating and Special Electrical Materials.

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT: Metallic and Non-Metallic Reactor Materials, Fuel Elements, Pressure Vessels, Control Elements, Related Equipment.

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT: Abrasives; Carbides; Coolants, Oils and Lubricants; Arc and Gas Cutting Equipment, Saws; Forging, Pressing, Extruding Chemical Milling, Slitting, Straightening and Spinning Equipment; Tool and Die Steels, Plastic and Other Short-Run Die Materials.

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES: Atmosphere Generators and Gases; Commercial Services; Furnaces; Controls, Indicators and Recorders; Induction, Flame and Salt Bath Equipment; Ovens; Pyrometers; Quenches; Samplers and Analyzers; Trays, Refractory Parts.

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES: Alkaline Cleaning, Pickling, Degreasing, Buffing, Polishing, Blasting, Plating Porcelain Enameling, Purifying, Painting Equipment and Supplies; Rust Preventives; Abrasives.

WELDING AND JOINING EQUIPMENT AND SUPPLIES: Gas, Resistance and Arc Welding Equipment and Supplies; Electrodes; Adhesives, Fasteners; Hard Surfacing, Brazing and Soldering Equipment and Supplies.

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES: Microscopes and Attachments; Analytical and Mechanical Equipment; Gages, Comparators, Hardness Testers, Nondestructive, Electronic and Other Scientific Inspection Equipment.

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES: Electric and Vacuum Melting Furnaces; Refractories; Ferro Alloys; Foundry Irons and Coke; Rare Earths; Alloying and Refining Agents; Annealing, Soaking and Sintering Furnaces; Rolling Equipment; Industrial Gases; Foundry Equipment and Supplies.

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS: Castings (Malleable, Gray Iron, Steel, Non-Ferrous), Forgings, Extrusions, Powder Metal Parts, Springs, Stampings, Tubings, Weldments, Wire.

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Your best move is to UNITRON...

for a COMPLETE LINE of METALLURGICAL MICROSCOPES!

UNITRON'S Complete Line of Metallurgical Microscopes and Accessories covers the needs of Research, Industry and Education.

Quality optics . . . advanced optical and mechanical design . . . unique and convenient operational features . . . budget prices . . . free trial period — these, together with proven performance are the reasons why . . .

THE TREND IS TO UNITRON!

Circle 425 on Page 48-E

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INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO
204-206 MILK STREET - BOSTON 9, MASSACHUSETTS

Please rush UNITRON's Microscope Catalog 2-E

Name_____

Company_____

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Where
maximum cleanliness is a "must"... EXLO® "75" Extra high in chromium and extra low in carbon, EXLO "75" is specially designed for use in very low-carbon stainless steels and heat-resistant alloys. There are two grades to choose from—.015% max. carbon and .025% max. carbon—both of which contain a minimum of 75% chromium. Because of its exceptional cleanliness, EXLO "75" is particularly adaptable to vacuum melting and other processes requiring minimum contaminant elements.

And don't forget the EXLO Standard Grades for use in low-carbon stainless and heat-resistant steels, irons and alloys. Like all EXLO ferrochromium alloys, they have high density and maximum cleanliness. Write for information or call your nearest VCA District Office. Vanadium Corporation of America, 420 Lexington Avenue, New York 17, N.Y. · Chicago · Cleveland · Detroit · Pittsburgh.

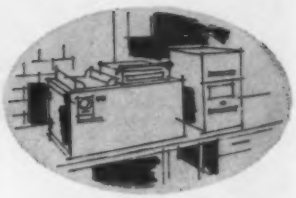
VANADIUM
CORPORATION OF AMERICA
Producers of alloys, metals and chemicals

VANCORAM

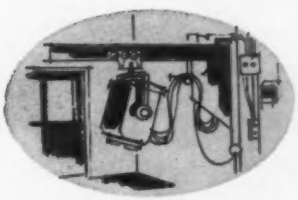
Circle 452 on Page 48-B

Nine different ways...

TVX
remote-inspection unit

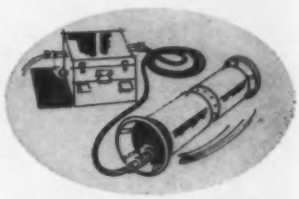


Xeroradiographic unit for
dry-process radiography



OX-250 general
utility x-ray unit

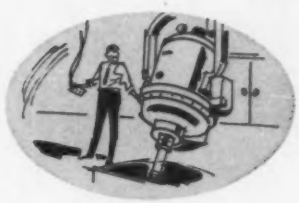
Resotron 300*—
300-kvp portable x-ray



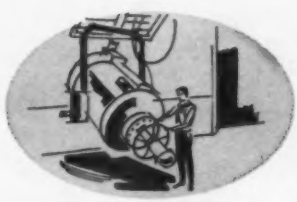
OX-175 — 175-kvp
portable x-ray

LX-140 — ultra-compact
portable x-ray

LC-90 lightweight
mobile x-ray



Resotron 1000*—
million-volt x-ray



Resotron 2000*—
2-million volt x-ray

to look at your products!

Let General Electric X-Ray lend a hand

G-E x-ray inspection equipment covers every need — with units available in power ranges from 5 to 2,000-kvp output . . . choice of wet or dry radiographic processing . . . even *remote-television* x-ray fluoroscopy. Production-line, continuous inspection can easily be arranged where desired.

There's no need at all to settle for piecemeal help when you want x-ray apparatus, supplies or installation-planning assistance. Instead, take advantage of the industrial x-ray experience General Electric has gained through half a century of serving needs and solving problems much like your own. You stand to come out ahead in many ways. Our specialists have the knowledge that can find right answers in a hurry. Our research facilities are set up to solve even the most unusual puzzles.

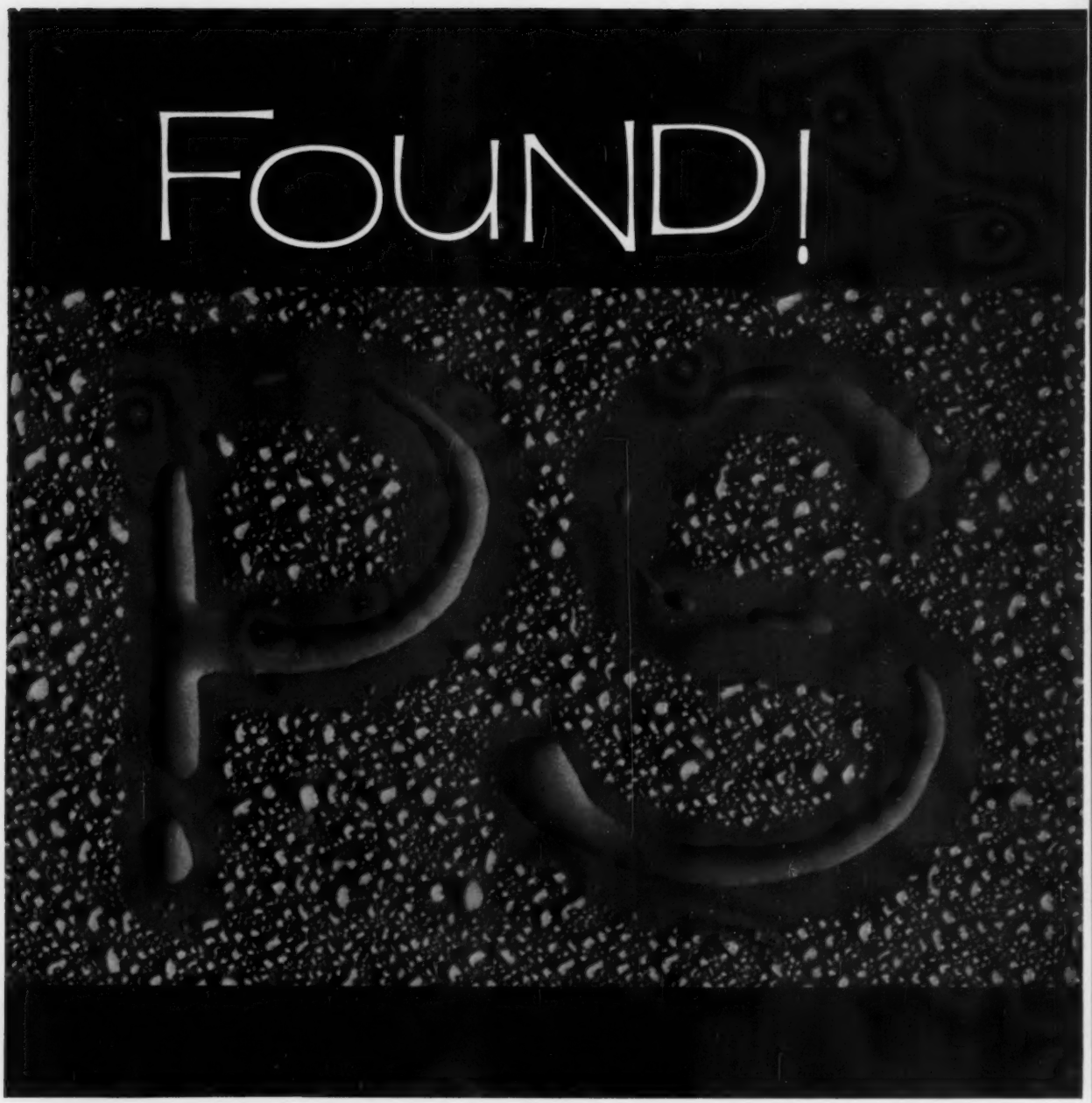
For assistance with your inspection problems, contact our office in your area, or just write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, Room AS-74.

* REGD. T.M.

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle 426 on Page 48-B



A WAY TO DEGREASE MORE PARTS PER DOLLAR OF CLEANING COST

What makes the big difference in vapor-degreasing cost?

It's not what you pay for solvent. It's how long your solvent keeps working between degreaser cleanouts.

WHAT'S PSP? It means "permanent staying power." It's what you get with Nialk TRICHLOR. The stabilizer in this solvent doesn't wear out. You don't need to add fresh stabilizer when you degrease with Nialk TRICHLOR. You don't have to check the pH. The stabilizer stays with the solvent and keeps on protecting it. In the bath. In the vapor. Even after repeated distillation.

WHY IS PSP IMPORTANT? Users report substantial savings with this better, more stable trichlorethylene. Degreasers run without shutdown for weeks—even months longer between cleanouts, in many cases. Rejects are down sharply. Less solvent is needed, because less goes down the drain in unnecessary cleanouts.

To start saving in your plant—soon—see your Nialk TRICHLOR distributor. He can show you why your best buy is the solvent that doesn't wear out prematurely. Call him today.

NEW 36-PAGE BULLETIN explains fully how you get more and better vapor degreasing for the money with Nialk TRICHLOR. Shows basic types of vapor degreasers. Discusses cycles, operating procedures, stabilizers, causes of solvent contamination, solvent recovery, trouble shooting. Ask your distributor for a copy or write us.

Nialk® Trichlor, a product of
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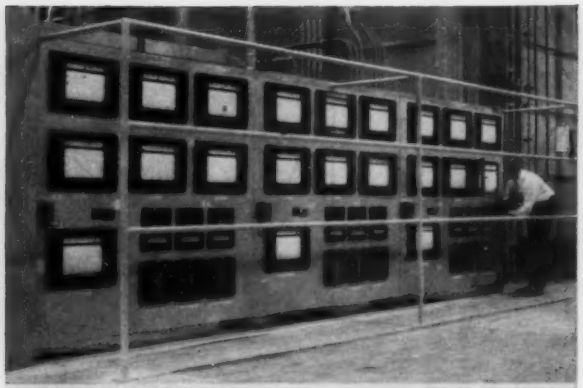
HOOKER CHEMICALS PLASTICS

Sales Offices: Buffalo Chicago Detroit Los Angeles New York Niagara Falls Philadelphia Tacoma Worcester, Mass.
In Canada: Hooker Chemicals Limited, N. Vancouver, B. C.

Circle 427 on Page 48-B

SOAKING. These Bristol Dynamaster* instruments monitor soaking pit operation in new, multi-million-dollar aluminum fabricating plant of Anaconda Aluminum Company at Terre Haute, Indiana. Staff engineer analyzes record.



ANNEALING. Dynamaster* instruments here control and record annealing furnace temperatures in new Anaconda Aluminum plant. Over 11½ acres under one roof, the new plant produces aluminum sheets, extrusions, tubes and ingots.

HEAT TREATING. Anaconda staff engineer checks temperature records, produced by Bristol Dynamaster instruments, for vertical extrusion heat-treating tower, part of which is shown at left.

AGING. Dynamaster instrument panel at left controls and records temperatures in aging furnaces in new Anaconda Aluminum Company plant. Furnace operator at right is moving rack car into furnace.

BRISTOL INSTRUMENTS FOR THE METAL INDUSTRY

The key to higher quality, more uniform production, greater efficiency

Bristol offers pyrometers for every requirement: Electronic potentiometers (including miniature models), millivoltmeter and radiation types... for furnaces, ovens... every type of heating equipment, every kind of fuel.

Bristol Dynamaster* electronic potentiometer pyrometers, service-tested and proved in thousands of industrial plant installations, fully measure up to the requirements of today's most advanced steel and metal-working plants. Check these modern features:

1. Continuous standardization—eliminates usual standardizing mechanism and dry cell... no interruption to control.

2. Simple, modular design—few moving parts.

3. Easy to use and service—minimum maintenance.

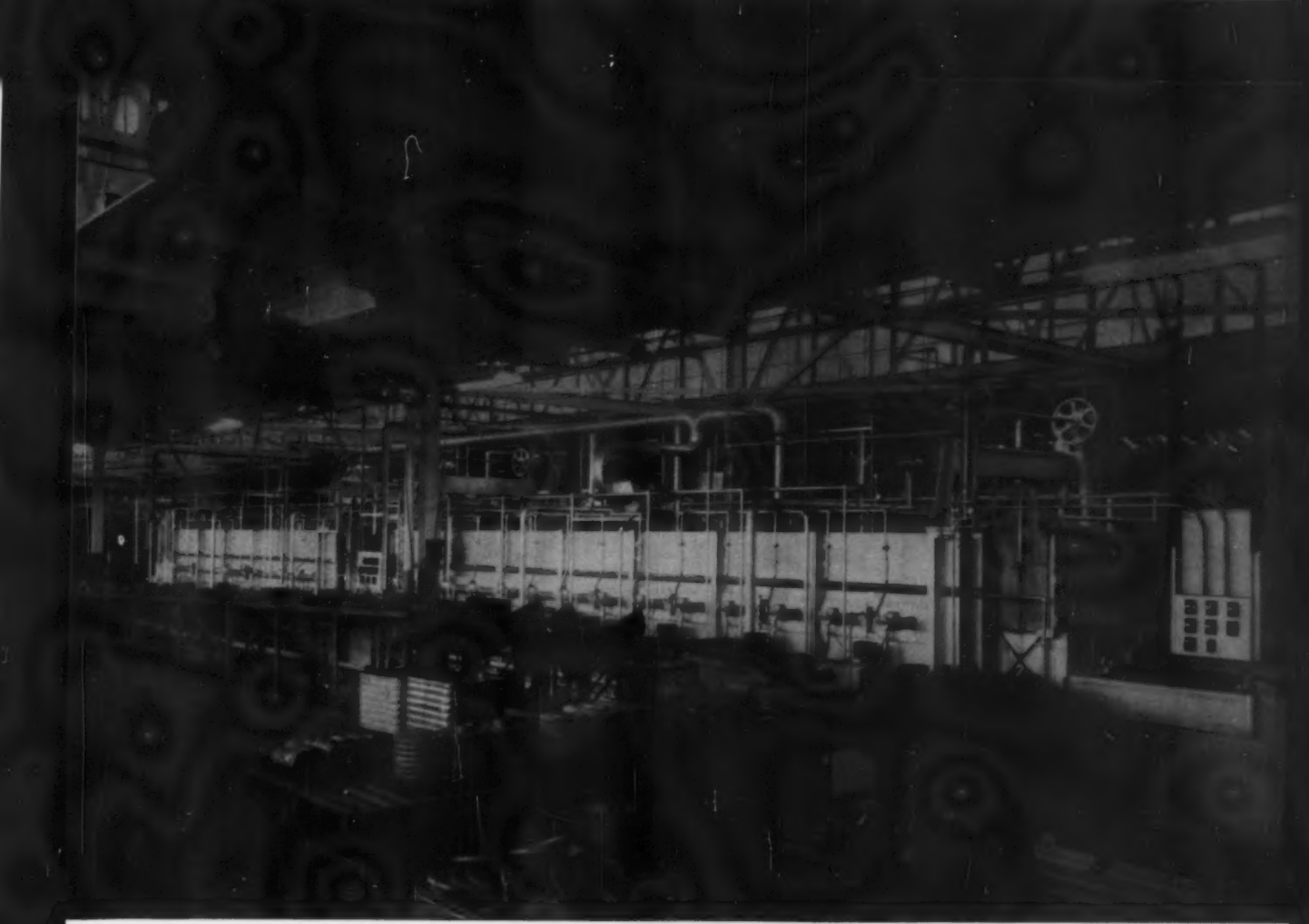
4. Rugged construction—continued accuracy and reliability under tough conditions.

Write for complete data—and remember, Bristol markets a complete line of pyrometer accessories available for fast delivery to keep your plant in operation. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn. *T. M. Reg. U. S. Pat. Off.

BRISTOL ...for improved production through measurement and control

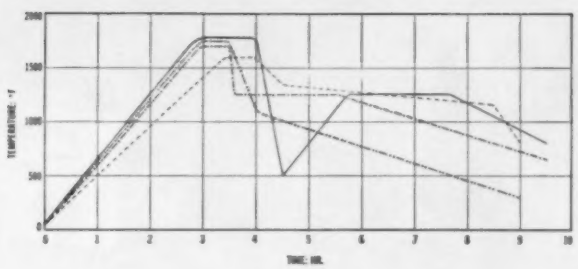
AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Circle 428 on Page 48-B



SELECT YOUR PRODUCTION AND DIAL YOUR CYCLE . . .

with this Salem-Brosius Continuous automatic cycle annealing furnace



Salem-Brosius cycle annealing and other heat treating furnaces are engineered to conform to your most exacting product specifications. Wide range heating and cooling cycles can be varied quickly and programmed positively—with a single operator—permitting you to handle a range of heat treating jobs with a single furnace. Such furnaces are built for continuous operation or as batch types, with conventional firing or controlled atmospheres. Your requirements govern design.

Both in the United States and abroad, Salem-Brosius is recognized for its outstanding design and construction of industrial furnaces—furnaces that yield maximum high-quality output at minimum capital, operating and maintenance costs.

When you need heating or heat treating furnaces, check with Salem-Brosius for advanced design and common-sense construction.

SALEM-BROSIUS, INC.

PITTSBURGH, PENNSYLVANIA

Circle 429 on Page 48-S

Salem Engineering Limited, Toronto, Ontario • Salem Engineering Co., Ltd., London & Milford, England • Salem-Brosius, S.A., Luxembourg • Salem-Brosius, S.A., Paris, France • Alloy Manufacturing Corp., Pittsburgh, Pennsylvania • R. H. Freitag Manufacturing Div., Akron, Ohio • General Ionics Corp., Pittsburgh, Pennsylvania.

3 All New electric

. . . to make

FEATURES:

- Wide band adjustments: 0 to 500% prop. band, 0 to 100 repeats/min. reset, and 0 to 10 min. rate.
- Bumpless transfer even when control output is changing.
- Change proportional band any amount without upsetting process.
- Rate action circuit minimizes overshoot in batch process and during startup.
- Pull-out chassis for servicing without interrupting operation.
- Modular construction simplifies maintenance and stocking.
- Plug-in silicon diode rectifiers for greater reliability.

All three units use the same plug-in components . . . only the control output section is different. Simplifies on-the-job servicing . . . eliminates need for complicated test equipment.

3-mode control units

furnaces perform at their best

***Electr-O-Line* Control Unit**—For electronic position-proportioning control with reset and rate action

***Electr-O-Pulse* Control Unit**—For electronic time-proportioning control with reset and rate action

***Electr-O-Volt* Control Unit**—For electronic current output proportioning control with reset and rate action

One of these units—*Electr-O-Line, Electr-O-Pulse* or *Electr-O-Volt*—will deliver the exact kind of temperature control that's best for your furnace.

Plug-in construction is used throughout all three units—including common amplifier and power supply sections. Operator adjustments are exactly alike for all three units. Interchangeability of control output sections simplifies stocking and service problems.

Get complete details on these and other types of furnace controls from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

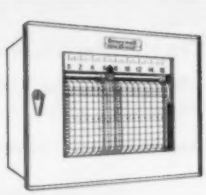
Honeywell

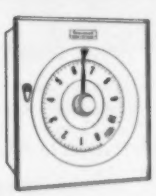
First in Control

SINCE 1885

75th YEAR

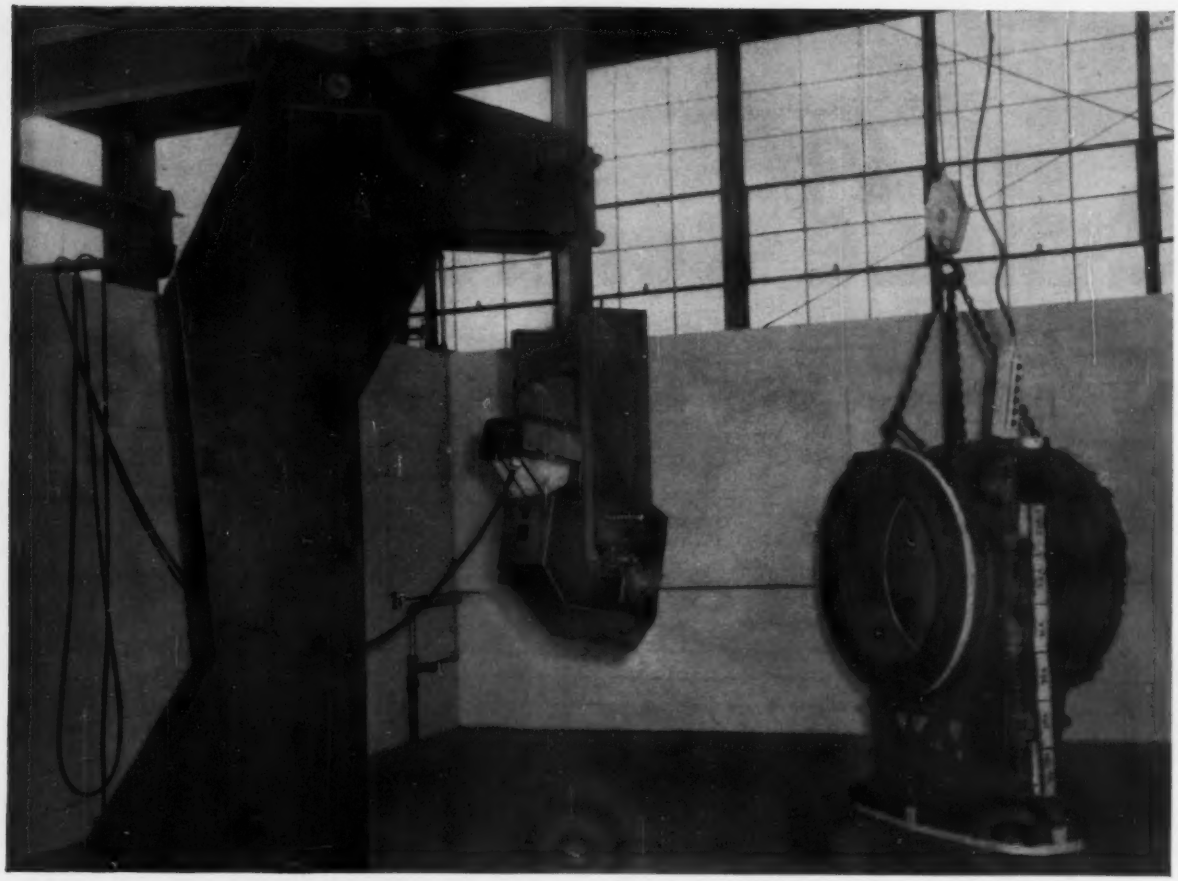
PIONEERING THE FUTURE





Use *ElectroniK* strip chart, circular chart or circular scale controllers to actuate *Electr-O-Line, Electr-O-Pulse* or *Electr-O-Volt* units. They are integrally mounted, simplifying panel cutout and reducing wiring costs.

Circle 430 on Page 49-B



A Model 1061 Multitron radiographing a large steel valve casting at Pacific Southern Foundries, Inc., Bakersfield, California, a subsidiary of Pacific Valves, Inc., Long Beach, California. Model 1061, a 1000 curie-cobalt 60 source, features fully automatic fail-safe protection and remote operation from a console control center. The special mounting stand was designed and fabricated by Pacific Southern Foundries, Inc. and Pacific Valves, Inc.

SAFE!... Budd® Multitron® and Iriditron® Units for Gamma Radiography

- **Hermetically sealed sources are under positive control at all times**
- **Shielding for sources is latest design**
- **Source position indicator shows exact location of source**
- **Fail-safe mechanism returns source to shielded head if power fails — on all units having electric drive**

Maximum safety with minimum weight: that's the story of Budd radiography equipment. You can select the equipment that best fits your requirements from the 21 standard Multitron and Iriditron models now available. One of the Budd models will give you the method or methods of exposure, number of sources, source materials, strength and types of mountings you need . . . all with maximum safety.

Budd offers complete service—radioactive source supply and encapsulation, source replacement and disposal, training for your personnel (at no charge) and assistance in setting up complete radiographic facilities.

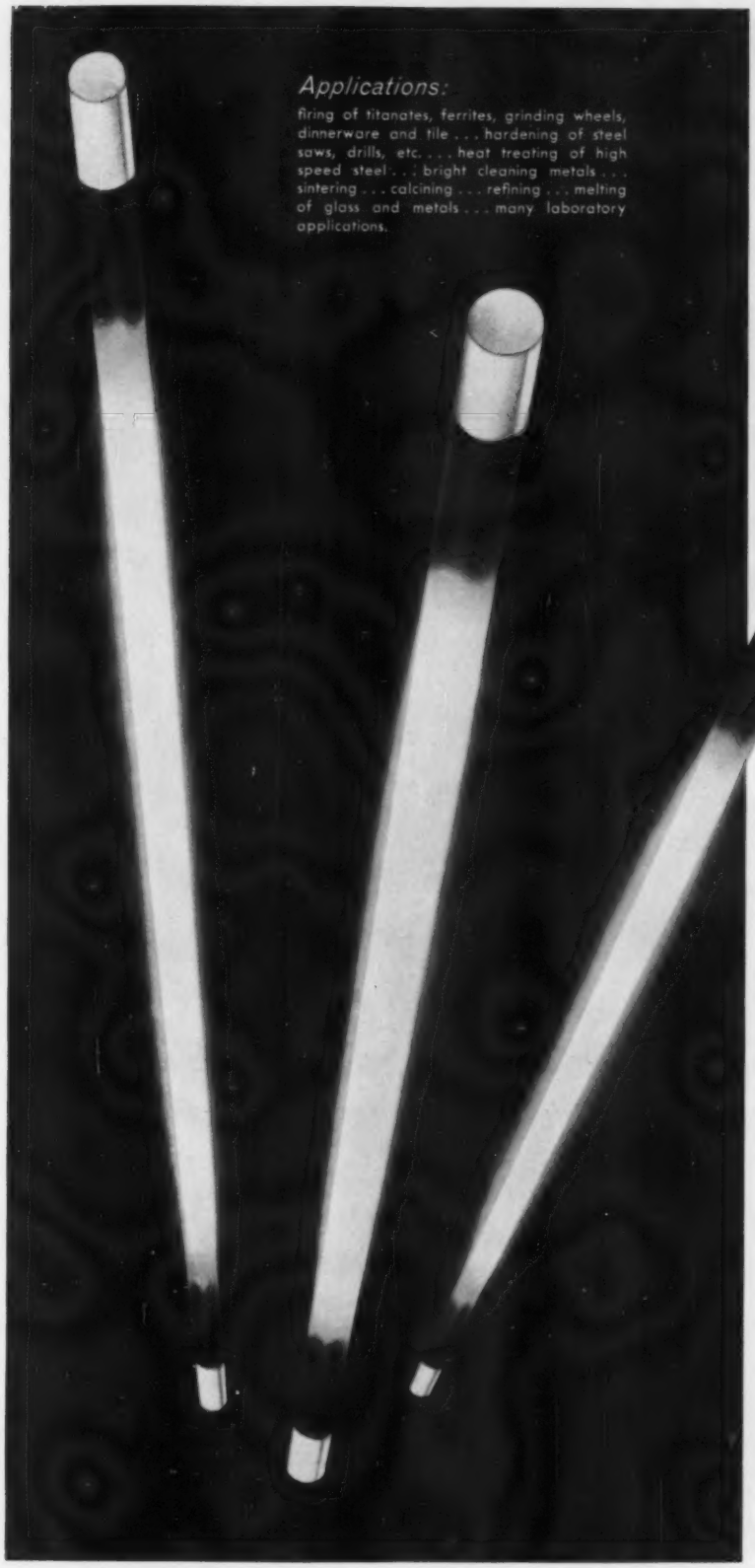
Contact Budd Instruments Division for new Gamma Radiography bulletin . . . or for a consultation on your requirements.

INSTRUMENTS Budd DIVISION

THE BUDD COMPANY • P.O. Box 245 • Phoenixville, Pa.

Consult your phone book for sales offices in: Atlanta, Ga., Oak Park, Ill., Dallas, Tex., Los Angeles, Calif., San Francisco, Calif.
In Canada
Tatnall Measuring and Nuclear Systems, Ltd., 46 Hollinger Rd., Toronto 16, Ont.

Circle 431 on Page 49-B


Applications:
firing of titanates, ferrites, grinding wheels, dinnerware and tile . . . hardening of steel saws, drills, etc. . . . heat treating of high speed steel . . . bright cleaning metals . . . sintering . . . calcining . . . refining . . . melting of glass and metals . . . many laboratory applications.

Perform brilliantly!

Norton CRYSTOLON* "Hot Rods" consistently outlast other types of non-metal electric heating elements . . . both in intermittent and continuous operation . . . in furnaces and kilns. They require less frequent changing and fewer changes in voltage taps. One-piece, non-welded "Hot Rods" are straight and strong . . . provide unmatched heating uniformity, electrically, efficiently, economically. Standard sizes readily available. Send for booklet: *"Norton Heating Elements."* NORTON COMPANY, 326 New Bond Street, Worcester 6, Mass.

*Trade-mark Reg. U. S. Pat. Off. and Foreign Countries

NORTON
REFRACTORIES
Engineered . . . Rx . . . Prescribed

75 years of . . . **Making better products . . . to make your products better**

NORTON PRODUCTS: Abrasives • Grinding Wheels • Machine Tools • Refractories • Electro-Chemicals — **BEHR-MANNING DIVISION:** Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes

Circle 432 on Page 48-B

Superex is easily combined with other insulations such as Johns-Manville Thermobestos®, J-M 85% Magnesia or J-M Insulating Fire Brick.

Only Johns-Manville Superex insulation performs 3 ways better at high temperature!

Few industrial products are so outstandingly superior, or so widely used in their area of application, as Johns-Manville Superex® Insulation.

A block insulation formulated of diatomaceous silica and asbestos for furnace and other applications, Johns-Manville Superex brings many advantages to high-temperature service—each contributing to reduced construction, maintenance and operating costs.

Superex is installed with measurable savings in time and labor! It is easy to cut and handle . . . weighs only 2 lbs. per sq. ft. per inch thickness . . . available in a wide variety of large block shapes and sizes. At high temperature—the material's excellent insulating value, thermal stability and resistance to shrinkage keep fuel costs low. Equally important—Superex saves on maintenance, too . . . easily withstands the daily abuse of normal service.

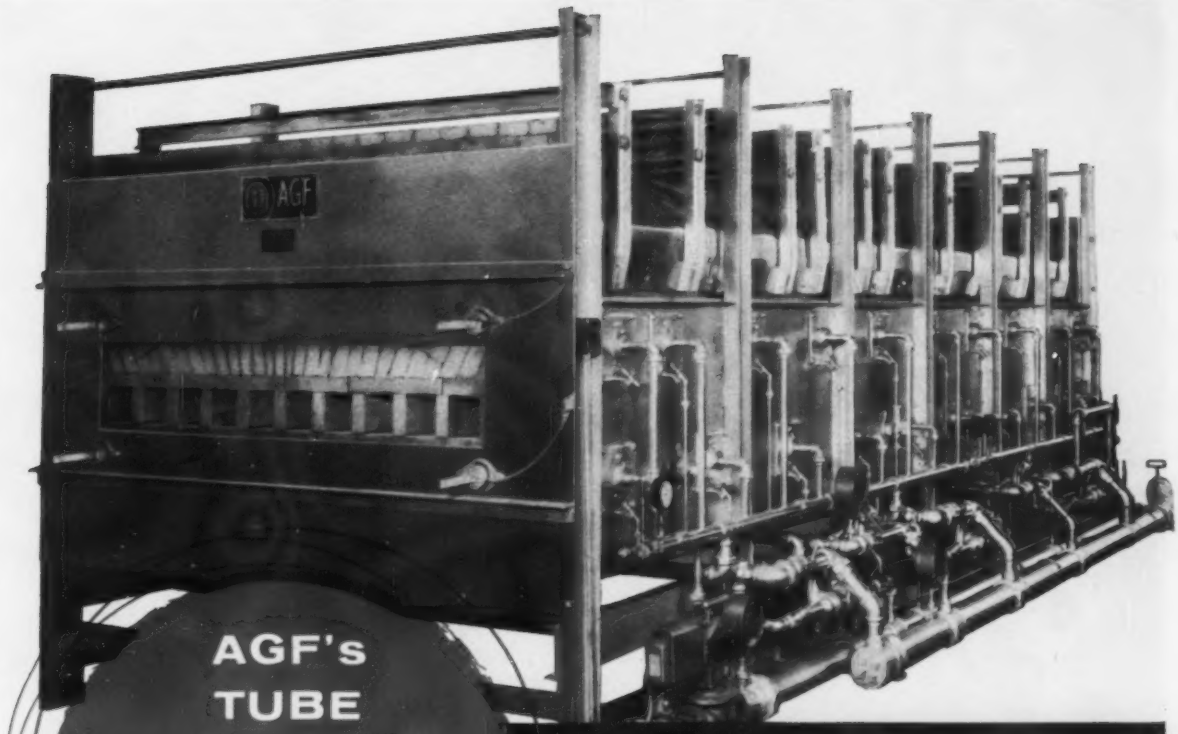
Send for your copy of IN-190A, the 12-page design and technical data brochure. It lists suggested applications—gives complete heat transmission tables and performance data. *Write for it today.* Address Johns-Manville, Box 14, N.Y. 16, N.Y. In Canada, Port Credit, Ont.

Saves waste. Superex comes in 7 standard thicknesses from 1″ to 4″. Other sizes available on order.

JOHNS-MANVILLE

JOHNS-MANVILLE JM PRODUCTS

Circle 433 on Page 48-B



AGF's TUBE FURNACES

for

WIRE, STRIP and POWDERS

ANNEALING	Steel, Stainless Brass, Copper, etc.
HARDENING	Steel and Stainless Wire and Strip
REDUCTION	Tungsten and Molybdenum Oxides
PATENTING	Steel Wire

AGF's single and multiple tube muffle furnaces, in a complete range of sizes, maintain completely uniform protective atmospheres within the alloy muffles.

Removable roof covers provide easy access to the heating chamber and muffle tubes for maintenance and inspection—greatly reducing maintenance "down time"

Advanced combustion system incorporates numerous specially designed AGF piloted combustion blocks of small heat input to provide TEMPERATURE UNIFORMITY which CANNOT BE OTHERWISE OBTAINED.

Multiplicity of burners and individualized control zone construction of heating chamber and combustion system permit EXACT regulation of any of the control zones at a desired temperature.

Send for your copy of AGF's new and complete catalog of heat-treating equipment and accessories, as well as for detailed information concerning specific problems and equipment.

AMERICAN GAS FURNACE CO. 82 YEARS OF PIONEERING 1878 1960 ELIZABETH, N. J.

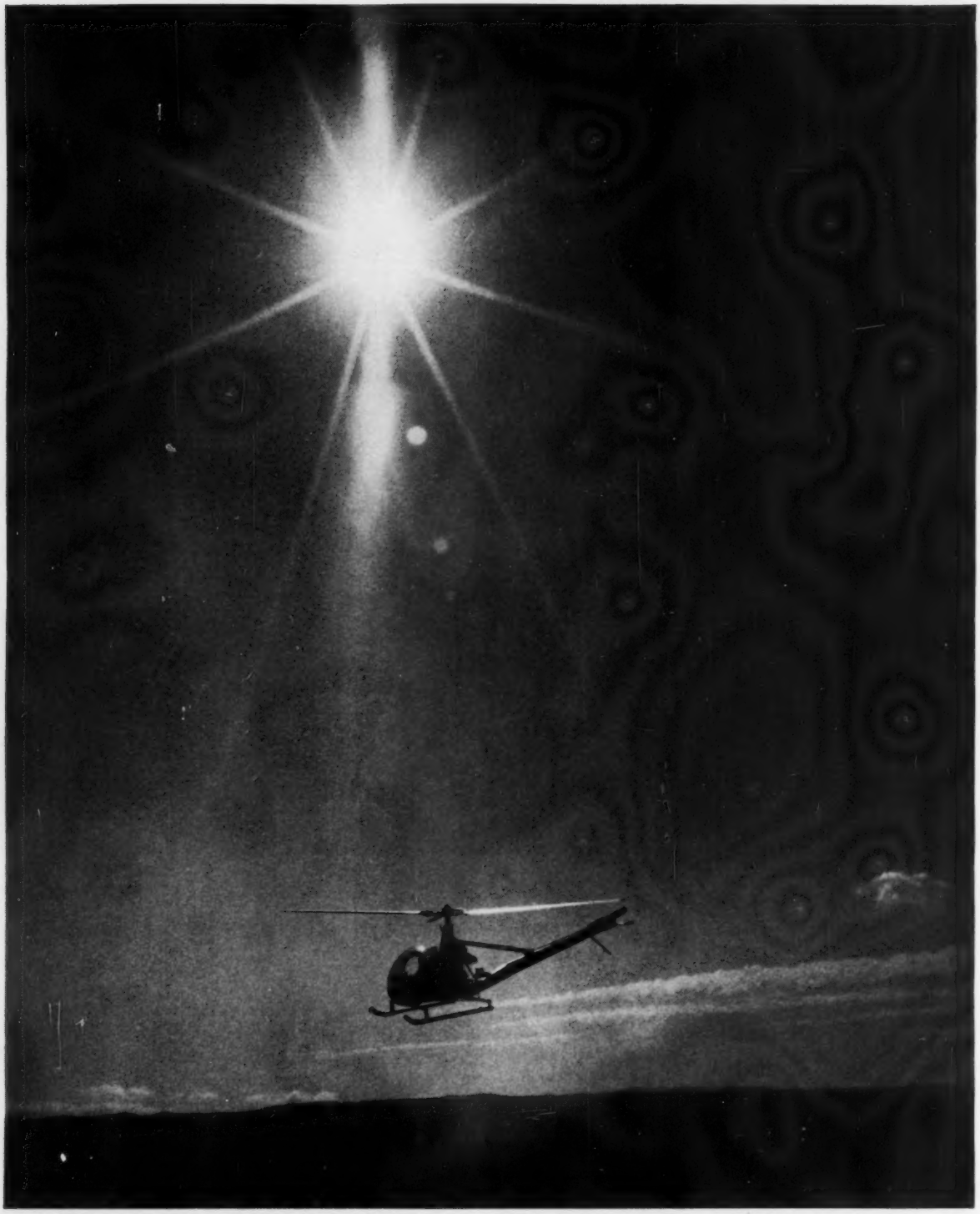
AMERICAN GAS FURNACE CO. PIONEERS 1878

CODE OF ETHICS SIGNER

AMERICAN GAS FURNACE CO.

1002 LAFAYETTE STREET • ELIZABETH 4, N.J.

Circle 434 on Page 48-B



This bird grew up in a Gas-heated nest. The nest is the plant of Hiller Aircraft Corporation in Palo Alto, California, where gas is used exclusively in the heat processing of aircraft parts. From the big bubble up front to the rotor blades in its tail, nearly every part of a Hiller helicopter is processed with gas heat. Gas heat cures plastics, anneals metals, dries paint, heats solutions for plating . . . keeps the plant itself warm in winter. Hiller Aircraft—and thousands of other companies—use gas heat because it is completely controllable, fast, clean, economical. Gas is technically right and economically sound for all types of heat processing. Call the Industrial Sales Engineer at your local gas company for specific technical help. *American Gas Association.* **FOR INDUSTRIAL HEATING GAS IS GOOD BUSINESS**

Circle 435 on Page 48-B

Fabricating parts from long lengths of "premachined" shapes reduces machining, scrap, and finishing

The lock components shown above are typical of some 20 different precision brass parts which Welch, Inc., Waukegan, Ill., makes for its broad line of locks and latches, from Anaconda extruded shapes.

Welch works closely with Anaconda specialists from early design stages. New lock mechanisms are built around parts which can be cut by a metal slitting saw from long lengths of extruded shapes with minimum subsequent machining and scrap. The use of bar stock is never considered when there is the slightest possibility of designing savings into a part by means of a brass extrusion.

Superior quality, too. Parts made from extruded shapes are characterized by their strong, homogeneous, wrought-metal structure. And the smooth, extruded surfaces reduce many finishing operations.

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Circle 436 on Page 48-B

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Metal Progress

Vol. 78, No. 1 July 1960

Technical NEWS in Brief

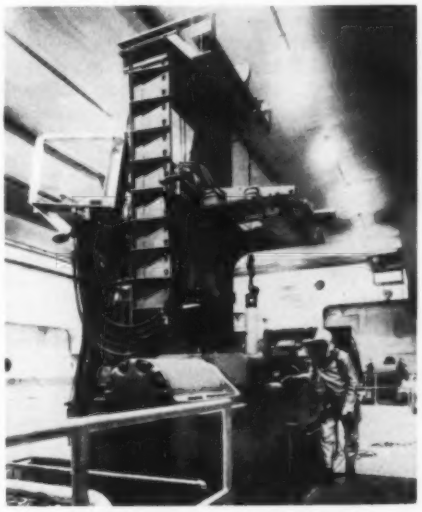
Refractory Metals Worked in Argon-Filled Room

More and more, modern technology continues to advance in unexpected directions. Now, comes the announcement that research facilities at Universal-Cyclops Steel Co. have been augmented by a large room (42 × 97 × 23 ft. high) filled entirely with purified argon! In it the company has installed a rolling mill, an impactor for forging and equipment for heating refractory metals to 4000° F. and higher. A 10-ton crane, which can be controlled from either inside or outside, carries material and tools within the room. Also included is a massive argon purification system. The entire installation is called "Infab" (for inert fabrication).

A "spaceman" in the room (see photo) serves chiefly as a troubleshooter since all rolling and forging equipment is remotely controlled from outside. This elaborate and costly setup, built in cooperation with the U.S. Navy, represents quite an advance in metals technology.

Why is such a complex facility necessary? The answer lies in the metallurgical characteristics of the four important metals in the refractory group. All of them – molybdenum, columbium, tantalum and tungsten – have very high melting points, ranging from around 4400° F. for columbium to about 6100° F. for tungsten. As a consequence, their hot working temperatures are also quite high, being empirically established at 85% of the melting points. At these temperatures all metals oxidize readily, and their surfaces are easily contaminated by reactive gases such as oxygen and nitrogen. Because of this, the refractory metals must be fabricated at a temperature well below that which is ideal for hot working. In fact, they receive what might be called "hot-cold" working in that they are processed below their recrystallization temperatures. As would be expected, of course, some of the strength in bars and sheet is due to this "cold" working at around 2200° F., the conventional working temperature for these metals.

With the new installation, which provides an



Forging Setup in Argon-Filled Room
Molybdenum Ingot Will Be Heated to 4500° F.

inert atmosphere for processing the refractory metals without danger of surface contamination, engineers at Universal-Cyclops expect to hurdle the temperature barrier. At first, their experiments will probably be confined to molybdenum and columbium since they can be hot worked readily in the 4000 to 4500° F. range. Later – as more is learned about the equipment – research will begin on tantalum and tungsten, both of which must be processed at much higher temperatures. To look further into the future, engineers at the company predict that the room will be used for small production lots, and that larger "Infabs" will be erected.

More Parts From Stainless Steel Powders

At the meeting of the Metal Powder Industries Federation in Chicago recently, W. L. Batten, Vanadium-Alloys Steel Corp., presented data to show that parts sintered from stainless steel powder (Type 316, prealloyed) at 2050° F. have mechanical properties which are adequate for many applications. The lower sintering temperature means economy in production. The most practical sintering atmospheres from the viewpoint of cost and control are dissociated ammonia and pure dry hydrogen. Extra strength and ductility, when needed, can be achieved through additional processing of parts.

Cost saving continues to be the main reason for fabricating stainless steel parts by the powder metallurgy process. For example, a small cam and pawl for a watt-hour meter are made from Type 304 powder at less than the cost of stamped and machined parts, and tolerances and surface finish are improved. Both parts must function smoothly under all sorts of climatic conditions. One of the largest pressed and sintered parts produced today measures 3⅜ in. in outer diameter. It is made from Type 316 and replaced a solid machined part at a cost saving.

Porous metal filters made from powders such as Type 304, 316 and 347 have many outstanding features. They will withstand great pressure differentials and can be used from —40 to 1500° F.

STAINLESS PARTS BY POWDER METALLURGY
Intricate Sprinkler Nozzle Made From Type 304 Powder

Stainless steel powders compounded with oxides, borides, nitrides and carbides show great potential for elevated-temperature service. A breakthrough in this research effort will create many new applications, according to Mr. Batten.

Steel Industry Consumes More Oxygen

How can we increase the output of our existing steelmaking facilities? Since many of the key steps in steel production depend on oxidation reactions, the obvious turn in recent years has been towards more use of oxygen. Experience has shown, for example, that enrichment of the blast with 1% oxygen increases blast furnace production by 4 to 5%. In the openhearth, roof lances carrying either 100% oxygen or oxygen-fuel mixtures have shown great promise. And openhearth temperatures can be upped for faster meltdown by injecting oxygen beneath the end burners.

In Europe a new wrinkle has been added to electric steel production. One plant there uses a setup in which oxygen, lime and limestone are blown on pig iron in a pre-refining step before the metal is charged into the electric furnace. Starting with a charge containing about 15% scrap, the technique will produce about 20 tons of refined metal every 1½ hr. Carbon is taken down to about 2.5%; phosphorus is cut from 0.5 to 0.05%. Since the first heat was poured last December, production from two 40-ton electric furnaces has gone up to 3600 tons per week.

Also in Europe (and in South Africa) the newer oxygen converter processes – L-D, Kaldo and rotor – are either well established or are picking up. Kaldo and rotor techniques are basic processes and use rotating converters which permit the metal to pick up heat from the lining. Looking into the future, it seems possible that we may see the use of oxygen-fuel lances in the L-D process. This will give a source of external heat and thus allow more scrap to be used.

Burnt Lime and Oxygen Increase Steel Output

The methods used to increase openhearth steel production, recently announced by Ford Motor Co., are basically a scheme for reducing meltdown time by pouring heat into the charge at a very high rate. This is achieved by employing two known practices. The charge contains burnt lime (CaO) instead of the usual limestone ($CaCO_3$), and it is melted by roof lances which inject oxygen and fuel together. By using burnt lime, the heat which would normally be needed to break down the limestone (to CaO) would instead aid in melting the total charge. Also, oxygen and fuel combined at the lance tip produce a very hot flame (4800 to 5000° F. is possible). By using this new practice, Ford can make a 200-ton heat of steel in about 3 hr.

Basically, the charge consists of 50% scrap and

50% hot metal with burned lime. The scrap is charged rapidly, while a high firing rate is maintained with oxygen flame enrichment and oxygen-fuel through roof lances. As soon as scrap and burned lime are charged, the doors are banked and the hot metal is added. High heat input continues until the scrap is completely melted. At this point, the firing rate is reduced, and the heat is treated as an oxygen lance heat. A high rate of oxygen flow is maintained. Ore has given the best results in controlling the rise in temperature.

To date, Ford has made more than 15 heats in both 200 and 400-ton openhearths. In the 200-ton furnace, a composite heat average of 67.6 tons per hr. has been obtained; limited data show that about 100 tons per hr. can be obtained from the 400-ton furnace. These outputs are about double those of the same furnaces with conventional oxygen lance methods.

Lubrication With Ice

Spring back of sketch-formed items – especially of hard, strong sheet – is a serious matter and is intensified if the lubricant is squeezed out of high-pressure areas between metal and form. When the form or die is so constructed that it can be kept at, say 17° F., cold enough to freeze a 2-mm. layer of ice when water is sprayed on it, and the metal is kept mildly warm during the operation by infrared radiation, spring back may be cut to as little as one third the amount when using S.A.E. 40 oil. Pressure between sheet and ice melts just enough of the latter to form an effective lubricant.

New Alloy for Metal-to-Ceramic Seals

Metal-to-ceramic seals can be troublesome unless the expansion characteristics of both materials are at least nearly the same. Technology has not advanced far enough to do much with ceramics, but we can tailor the thermal expansion of metals by alloying and special melting procedures. This has been done by General Electric which recently announced a new alloy called Fernico-5; it undergoes much less expansion and contraction than other metals.

The result of work by Gordon D. Oxx (see photo), Fernico-5 is an alloy of nickel and cobalt in iron. It has a coefficient of thermal expansion close to that of alumina, and thus permits the use of this ceramic in electron tubes, thermionic energy converters, capacitors and high-temperature circuits. All of these items require metal-to-ceramic seals.

Since the alloy is vacuum melted, there is no need to add manganese or silicon to tie up oxygen. Low gas content makes the alloy well suited for use in vacuum and special atmospheres. Further, expansion characteristics are consistent because the composition can be more closely controlled. This is particularly important since a minor variation in the ratio of iron, nickel and cobalt can cause a transformation from the normal face-centered cubic structure to body-centered cubic near room temperature.

ENGINEER CHECKS THERMAL PROPERTIES
Expansion of New Iron Alloy Matches That of Alumina

A Better Way to Weld HY-80?

Adaption of the versatile CO_2 processes which are based on rapid short circuits between electrode and work may simplify welding of thick sections of HY-80. This steel, a low-alloy grade which attains high strength through quenching and tempering, has been used for pressure hulls of atomic submarines which are fabricated by welding. C. R. Sibley, Air Reduction Sales Co., reported at the recent annual meeting of the American Welding Society that methods such as Dip Transfer and short arc have a distinct advantage. They can be used to weld in all positions, thus eliminating much of the need for positioning equipment and the restriction that welds must be made only in the flat position. Any method, however, must produce welds which exceed 88,000 psi. yield, 20 ft-lb. impact strength at −60° F. and 14% elongation. Further, the Navy wants welds which will pass its ballistic tests.

Best practice with these relatively new processes calls for a shielding gas containing 20% CO_2 and 80% argon. With this mixture, strength and elongation are, respectively, 99,000 psi. yield, 111,000 psi. tensile and 19%. Impact properties decrease as more carbon dioxide is added. Charpy impact strength is about 29 ft-lb. at −60° F. when the 20-80 mixture is used; at 50-50 it drops and occasionally goes below 20 ft-lb. With 100% CO_2 shielding, impact values are about 15 ft-lb.

Loss of alloying elements increases as CO_2 content goes up. As an example, with the 20-80 mixture, manganese will drop from about 1.4% in the electrode to 1.0% in the deposit. Silicon may decrease to about 0.4% from 0.5%. Vanadium and molybdenum are not affected.

Another early problem – brought out by marginal performance in ballistic test – was lack of

fusion at stops and starts. Larger wire sizes than the 0.035 in. originally used minimizes this trouble. For example, improvement occurred when 1/16-in. diameter wire was used in the weld root with 0.045-in. wire for the remainder of the joint. Larger wire sizes, of course, increase the arc size and decrease the chances of getting cold laps.

Materials Progress in Ceramics

In the technological race, we are just about holding our own in advanced systems design, but in materials progress, we are losing ground. For example, we need more basic knowledge about ceramics before they can be used to any great extent to solve the engineering problems which are already with us and which promise to become more acute. These statements came from John R. Townsend, special assistant to the director of defense research and engineering, in addressing the annual meeting of the American Ceramic Society in Philadelphia. Dr. Townsend suggested several important areas of investigation such as new methods for compounding and forming ceramics, formulations for high-temperature cements, methods of bonding ceramics to metals and more study of physical and mechanical properties of metallic oxides, borides, carbides, nitrides, silicides and sulphides which in many instances stand up better in severe environments than the parent metals.

Ceramics offer great potential because of their heat resistance and ability to retain strength at elevated temperature. But they lack ductility, a characteristic which is aggravated by porosity and large grain size. While metals can be hot worked, ceramics can not. Neither can they be welded.

The problem of brittleness can be approached in two ways – either by developing ductile ceramics or by learning to design with a brittle material, alone or in combination with other materials. Consider the potential of designs based on the latter approach. The Air Force has pointed out that by using this concept, components of power plants could be operated at 5000° F. without the need for auxiliary cooling. Thus an important barrier to progress in propulsion systems would be removed.

Experiments with single crystals demonstrate that ductility is possible. But the logical route seems to be in polycrystalline material aiming at finer grain size, higher density and greater purity. Perhaps changes in composition based on additions of thorium, yttrium and rare earth compounds may also bring improvements. However, we may not see ductile ceramics for another 10 to 20 years.

From Here and There

Recent work with solid lubricants has demonstrated that additions of inorganic sulphides to molybdenum or tungsten disulphide have a pronounced effect on lubricating efficiency. Investigators at General Electric Research Laboratory have found, for example, that when silver sulphide is added to molybdenum disulphide it increases the load-bearing ability of the lubricant by 20 times. Most effective sulphides seem to be those of antimony, platinum, silver, titanium and lead. So far they've been added in amounts up to 10 wt.%.

• • • •

Thickness tolerances for magnesium sheet destined for aircraft and missile skins have been halved, according to Dow Metal Products Co. The standard tolerance of ±0.004 in. was cut to ±0.002 in. for 0.050, 0.063, 0.071, 0.080 and 0.090-in. sheet in AZ 31 B, HK 31 A and HM 21 A alloys. Improvement in thickness control permits designers to figure closer on stress distribution where minimum permissible thickness is used as a base. Close tolerances also allow greater accuracy in computing the weight of parts.

• • • •

It has become apparent that the "stress-relief" of austenitic stainless steel vessels at the conventional moderate temperatures sometimes does more harm than good to the equipment in its expected service. Consequently the Welding Research Council is anxious to get pertinent information on this point from manufacturers and users. Especially desirable are actual case histories of equipment made of the Series 300 steels, whether stress-relieved or installed as-welded. Those possessing such information are urged to write G. S. Sangdahl, Chairman, High-Alloys Committee, Box 277, Birmingham 1, Ala.

• • • •

Titanium parts ranging in size from a few fractions of an inch to more than 35 sq. in. in cross section and only limited in shape by die design can be made by a powder metallurgy process recently introduced by Clevite Corp.

The advantage of powder metallurgy parts – less machining, close tolerances, high yield and production rate – do much to offset the cost of the metal. A. O. Schwope, director of the firm's mechanical research, reports that "titanium powdered metal components are economically priced so that they represent a low initial investment".

Tests Reveal Fracture Properties

Brittle fracture, which has been with us for a long time and is not yet fully understood, grows more acute in this day when we are demanding more of metal structures. A bridge fails, railroad rails crack, and ships break in half – we have cured these troubles by redesign, a change in heat treatment or by use of high safety factors. But what happens, for example, in a rocket motor case where design must be based on the lowest possible weight and highest strength? What is needed to start is a good measure of notch sensitivity or fracture toughness which will permit us to predict the performance of metals at high-strength levels. Some of the work along this line will be presented in a series of special articles in next month's *Metal Progress*. The problems are far from being solved. Perhaps you'll have a suggestion or two.

New Routes to Better Electroplate for Zinc Die Castings

*By W. H. SAFRANEK**

In answer to demands for better corrosion protection for zinc die castings, electroplaters have come up with three promising plating practices . . . duplex nickel, crack-free chromium and duplex chromium. Already in commercial use, these coatings provide long life to decorative and functional parts, particularly in automotive applications where corrosion is a severe problem. (L17; Zn, *Ni*, *Cr*, 5-61)

PRACTICES FOR ELECTROPLATING exterior automotive zinc die castings have changed greatly since 1957. In only two years, nearly all of the plating facilities have been modified extensively in order to adopt new procedures with a greatly improved capacity for providing more durable electroplated coatings. The decisions to make the equipment changes were based partly on the results of new accelerated corrosion tests developed under the research program of the American Electroplaters' Society

*Assistant Chief, Electrochemical Engineering Div., Battelle Memorial Institute, Columbus, Ohio. The author acknowledges with appreciation the permission of the American Zinc Institute and Battelle Memorial Institute to publish the information in this paper. The metallographic work by R. O. Buchheit and his associates at the Battelle metallographic laboratory is especially acknowledged. Figures 2 and 8 were republished with permission of the American Electroplaters' Society.

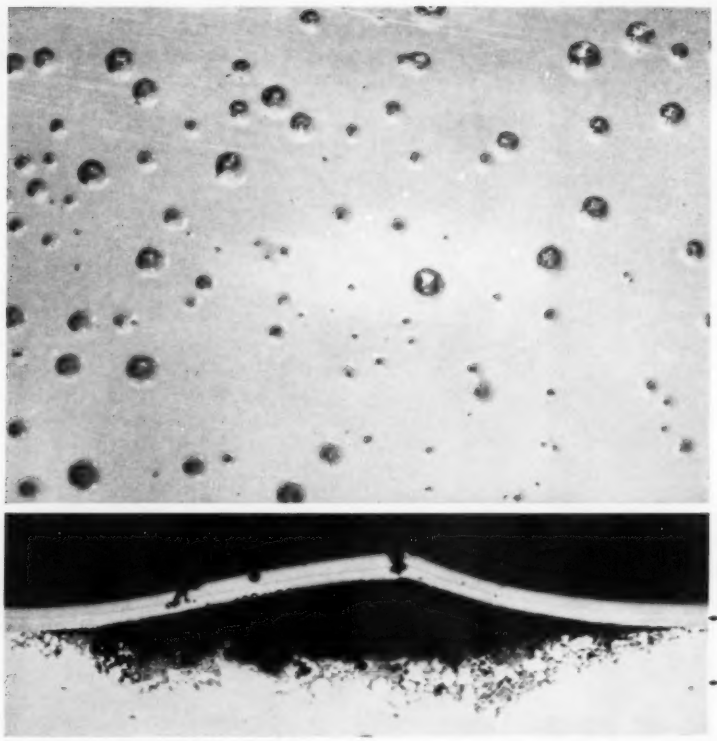


Fig. 1 – Die Casting Plated With 0.7 Mil of Copper, 0.9 Mil of Nickel, and 0.011 Mil of Chromium and Exposed 3 Winter Months in Detroit. Top: surface view, 10 ×; bottom: cross section through blister, 100 ×. Poor performance of this coating and that shown in Fig. 2, both of which were in common use during 1955 through 1957, prompted development of improved practices

and partly on roof exposure data. Recent service data have justified the wisdom of introducing the improved practices. Customer approval is expected for the improved performance that will be apparent for plated die castings on most 1960 models.

Old Practices Gave Poor Protection

Electroplating practices representative for die castings during the period 1955 through 1957 are outlined in Table I. Die castings so plated often acquired the badly blistered appearance shown in Fig. 1 and 2 after one winter (or less) of service. Previous investigations have established that the blisters developed as follows:

- Pit-type corrosion in the nickel plate began under discontinuities such as pores in thin (0.01 mil) chromium, or cracks in thicker (0.03 to 0.04 mil) chromium plate.
- Subsequent corrosion perforated copper and nickel plates at the pit sites.
- When the copper and nickel became perforated, zinc alloy corroded rapidly in a lateral direction.
- Bulky zinc corrosion products exerted pressure on the undermined copper, nickel, and chromium composite, raising the blister.

Table I – Electroplating Practices for Zinc Die Castings, 1955-1957

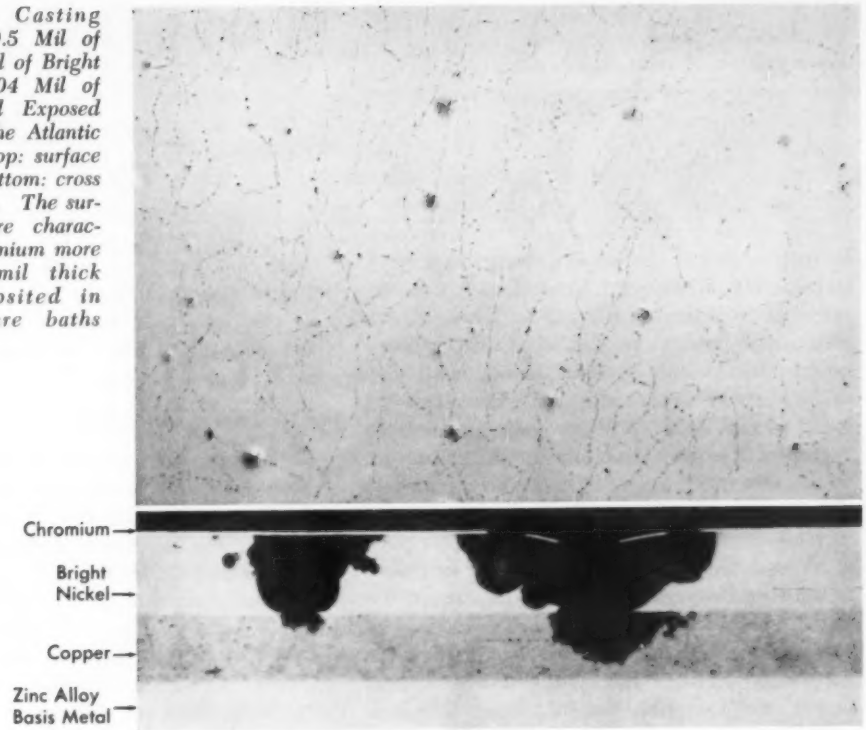
Electroplate	Minimum Thickness of Electroplate in Recesses	
	Method A*	Method B
Copper	0.3 to 0.5 mil	0.3 to 0.5 mil
Bright nickel	0.8†	0.8†
Chromium	0.01	0.03 to 0.04

*Method A was more popular than Method B.
†Parts with deep recesses often received less than 0.8 mil of nickel.

Duplex Nickel

The most popular of the improved practices, which are listed in Table II, includes a duplex nickel coating in place of a single bright nickel plate. The duplex consists of a layer of semibright nickel, deposited in solutions prepared with "sulphur-free" brighteners, and a thinner layer of bright nickel deposited in solutions prepared

Fig. 2 – Die Casting Plated With 0.5 Mil of Copper, 0.7 Mil of Bright Nickel and 0.04 Mil of Chromium and Exposed 3 Months in the Atlantic Coast Area. Top: surface view, 10 ×; bottom: cross section, 750 ×. The surface cracks are characteristic of chromium more than 0.025 mil thick that is deposited in low-temperature baths



with "sulphur-containing" brightners. The thickness of the bright nickel layer customarily is about 25 to 30% of the total nickel thickness.

Although pit-type corrosion is not eliminated by substituting duplex for bright nickel plate, pitting is inhibited when it reaches the semi-bright nickel interface, as shown in Fig. 3. Corrosion of the basis metal, therefore, is greatly delayed.

The selection of the brighteners for the semi-bright and bright nickel baths affects the performance of the duplex nickel. The use of sulphur-containing brighteners in the semi-bright bath, for example, reduces the durability of the duplex to that of a single bright nickel layer (of equal thickness). The selection of the brightener and its concentration in the bright nickel bath also influence durability, but to a lesser degree.

The pits in a properly applied coating become noticeable only after 18 hr. of exposure to copper-

Of interest to those concerned with metal finishing is the 47th Annual Convention of the American Electroplaters' Society which will be held at the Hotel Statler in Los Angeles July 24 through 28. Included in the program are a symposium on hydrogen embrittlement in metal finishing and sessions on corrosion resistance of plated automobile parts, precious metal plating and printed circuits, corrosion of magnesium, and cleaning techniques.

Table II – Current Practices for Electroplating Zinc Die Castings

Electroplate	Minimum Thickness of Electroplate in Recesses		
	Method C	Method D	Method E
Copper	0.3 to 0.5 mil	0.3 to 0.5 mil	0.5 to 0.8 mil
Bright nickel	—	—	0.8 to 1.0
Duplex nickel*	0.8 to 1.2	0.8 to 1.2	—
Chromium	0.01	—	—
Crack-free chromium	—	0.03 to 0.05	—
Duplex chromium	—	—	0.04 to 0.06

*Duplex nickel consists of one layer of semibright nickel and a second layer of bright nickel.

accelerated salt spray*, or after about 6 months of outdoor weathering. Such pits are less objectionable, of course, than the larger blisters customary for similar periods of exposure before the advent of duplex nickel on zinc die castings.

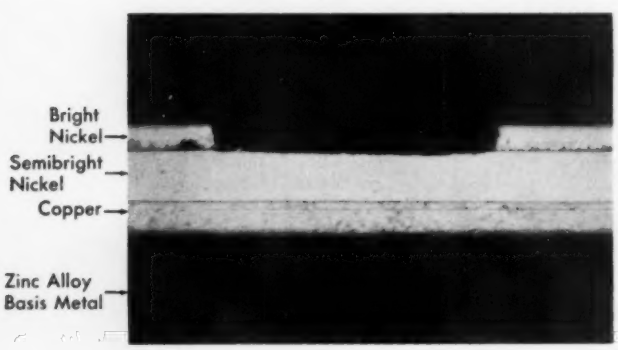
Long periods of accelerated corrosion cause each pit in duplex nickel to spread laterally, in preference to corrosion in depth. Examples of such a lateral spread are shown in Fig. 4 and 5. There has not been sufficient time to correlate such long periods of accelerated corrosion with outdoor weathering, but it appears safe to predict that at least 3 and possibly 4 or 5 years of weathering will be required to grow pits as large as those in Fig. 4 and 5.

Duplex nickel-chromium composites proved more resistant to cracking than bright nickel-chromium composites during gravel bombardment studies at Battelle under a research program sponsored by the American Zinc Institute. In and around each of the dents caused by gravel particles considerable cracking was observed on the surfaces of castings plated with copper, bright nickel, and chromium. As shown in Fig. 6, many of the cracks propagated completely through the bright nickel coating. Fewer cracks occurred in the dents in die castings plated with copper, duplex nickel, and chromium. Furthermore, those fewer cracks propagated only part of the way through the nickel coating.

The resistance to cracking of the softer and more ductile semibright nickel and its buffering action in limiting crack propagation into the harder, bright nickel overlay are advantageous. They mitigate the rapid basis-metal corrosion that occurs under the cracks in a single bright nickel plate. A remarkable contrast was observed in the relative corrosion performance of the duplex nickel and bright nickel-plated die castings, after gravel bombardment. Severe blistering occurred in the cracked dents in bright nickel-plated castings in less than 18 hr. of copper-accelerated salt spray; 36 hr. of exposure raised only a few blisters in the duplex nickel-plated castings.

*Salt spray fog at 120° F. with 5% sodium chloride solution prepared with 1 g. per gal. $CuCl_2 \cdot 2H_2O$ and adjusted to a pH of 3.1 ± 0.1 with acetic acid.

Fig. 3 – Corrosion Pit Arrested at Semibright Nickel Interface After Penetrating 0.3 Mil of Bright Nickel During 3 Months of Winter Exposure in Detroit. Chromium plate was 0.01 mil thick. 500 ×



Crack-Free Chromium

The use of bright crack-free chromium has been proposed to inhibit corrosion pitting in duplex nickel coatings. Crack-free chromium can be deposited in pore-free or nearly pore-free form if its thickness is increased to about 0.05 mil, when it is deposited over a smooth

Fig. 4 – Surface View of Zinc Die Cast Panel Plated With 0.4 Mil of Copper, 1.2 Mil of Duplex Nickel, and 0.01 Mil of Chromium Showing Large Corrosion Pits in the Duplex Nickel Caused by 144 Hr. of Copper-Accelerated Salt Spray. Most of the corrosion pits did not penetrate the duplex nickel coating

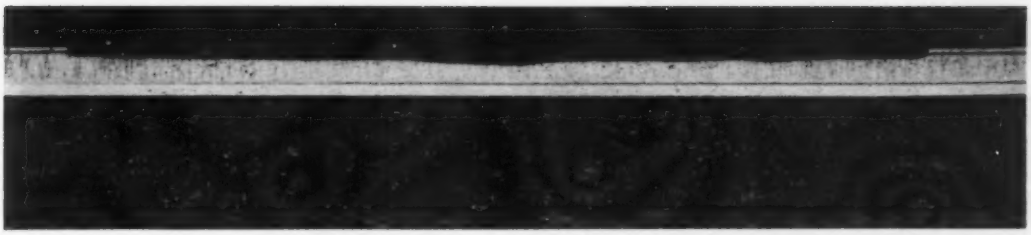


Fig. 5 – Cross Section of Corrosion Pit in Duplex Nickel Caused by 144 Hr. of Copper-Accelerated Salt Spray. Pit has spread laterally rather than penetrating directly to basis metal

pore-free and crack-free nickel coating. A crack-free and pore-free chromium offers no sites for corrosion to begin in the composite. Chromium is inert in industrial and seacoast atmospheres.

Whereas ordinary chromium is deposited in baths which are operated at 105 to 110° F. and contain about 100 times as much chromic as sulphuric acid (Table III), crack-free chromium is plated in high-temperature, high-ratio baths (HTHR) which are operated at 120 to 130° F. and contain about 150 times as much chromic as sulphuric acid. In comparison with ordinary chromium, which cracks badly when its thickness is increased to 0.03 mil or more, chromium deposited in HTHR baths is completely free of cracks up to a thickness of more than 0.25 mil. Although heating to 175° F. causes cracking in 0.16 to 0.3-mil thick HTHR chromium, ultra-sensitive techniques have failed to reveal any cracks in HTHR chromium plate up to 0.15 mil in thickness, even after more than 100 heating and cooling cycles (from about 70 to 175° F.). The cracks that appear in thicker, HTHR chromium are barely visible and are less unsightly than the cracks that can be seen in 0.03 to 0.05-mil chromium deposited in a low-temperature, low-ratio bath, such as that described in Table III. Furthermore, corrosion under the cracks in thick HTHR chromium occurs very slowly in industrial and marine atmospheres. For example, during 16 months of outdoor weathering, there was no change in surfaces plated with 0.16 to 0.4 mil of HTHR chromium.

As shown in Fig. 7, the cracks caused by heating 0.2-mil, HTHR chromium propagated only part of the way into the relatively thin, bright nickel overlay in a duplex system. By comparison, many of the cracks caused by heating thick HTHR chromium propagated completely through the thicker, single bright nickel used before the adoption of duplex nickel. Thus, duplex nickel is superior to a single bright nickel as an undercoat for HTHR chromium.

Bombarding gravel on die castings plated with a composite of duplex nickel and 0.05 mil of crack-free chromium caused less damage than it did on castings plated with a composite of duplex nickel and 0.01 mil of ordinary chromium. Although the incidence of cracking was about the same in both cases, less corrosion occurred under the cracks in the thicker chromium when die castings plated by these new practices were subjected to copper-accelerated salt spray after gravel bombardment.

The practicability of plating crack-free chromium on die castings of complex shape and its efficacy in inhibiting corrosion pitting and blistering in duplex nickel-chromium compos-

Table III – Conditions for Depositing Ordinary Chromium and Crack-Free Chromium

Condition	Ordinary Chromium†	Crack-Free Chromium‡
Chromic acid concentration, oz. per gal.	33 to 88	42 to 47
Sulphuric acid concentration, oz. per gal.	0.33 to 0.38	0.28 to 0.32
Ratio of chromic to sulphuric acid	95:1 to 115:1	135:1 to 160:1
Bath temperature, °F.	105 to 112	120 to 130
Cathode current density, amp. per sq.ft.	125 to 175	250 to 350
Cathode efficiency, %	About 13	About 14
Throwing power, % *	−65	−15
Plating rate, mil per hr.	0.3 to 0.35	0.5 to 0.7

*To improve covering power in recesses, the nickel-plated parts should be connected to a low-voltage power source when immersed in the high-temperature, high-ratio bath. A 2 to 4-volt cathodic treatment for 15 to 45 sec. has prevented rainbows in recesses.

†Low-temperature, low-ratio bath.

‡High-temperature, high-ratio bath.

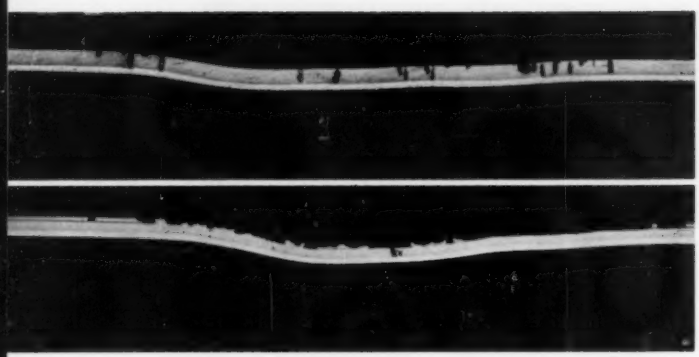
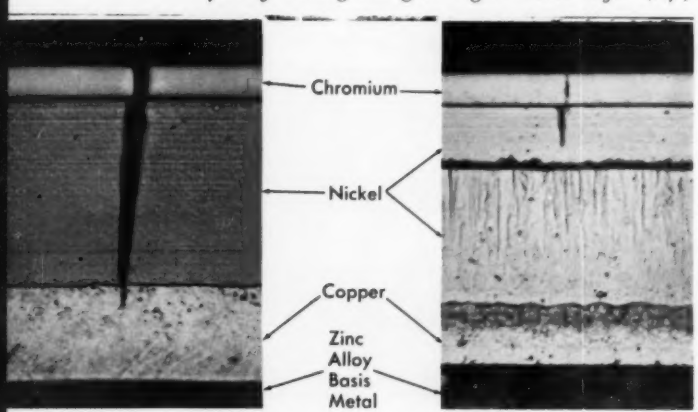


Fig. 6 — Cross Sections of Plated Zinc Die Castings Which Were Bombarded With Gravel. Top: copper-bright-nickel composite, 100 ×; bottom: copper - duplex - nickel composite. 100 ×. Gravel has caused deep-running cracks in copper-bright-nickel composite. Rough surface of copper-duplex-nickel composite is the result of corrosion in the bright nickel layer of the duplex system. This die casting was subjected to 36 hr. of copper-accelerated salt spray after it was bombarded with gravel

ites were demonstrated in the Battelle laboratories during the research sponsored by the American Zinc Institute. Confirmatory results are being obtained in day-to-day production in several plants that have adopted the process. During accelerated corrosion studies conducted at Battelle, die castings plated commercially with duplex nickel and crack-free chromium have withstood 72 to 90 hr. of copper-accelerated salt spray with either very few or no corrosion pits or blisters. Similar parts plated with 0.01 mil of chromium over duplex nickel usually showed severe surface pitting after 36 or 54 hr. of copper-accelerated salt spray.

Fig. 7 — Cross Sections of Cracks in Nickel-Chromium Composites Caused by Heating 100 Times From 75 to 175° F. Left: bright nickel-chromium composite, 1000 ×; right: duplex-nickel-chromium composite, 1000 ×. Cracks have penetrated completely through single bright nickel layer (left)



Duplex Chromium

Duplex chromium (Method E, Table II) is the most recent improved practice elevated to commercial status. A layer of chromium deposited in crack-free form in a mixed-catalyst, self-regulating bath is followed by a second layer of chromium which contains a microscopic system of crisscrossing cracks. The microcracks are not visible to the unaided eye. Under a 100-power microscope, more than 1000 narrow cracks can be counted per linear inch.

In practice, the thickness of the second layer is about equal to that of the first layer. Metallographic studies at Battelle have shown that all cracks in the outer chromium layer penetrated through the inner, initial chromium layer on die castings sectioned soon after plating. No crack propagation into the bright nickel undercoat was detected, however.

Despite the microcracking, duplex chromium over bright nickel offers surprisingly good corrosion protection to copper-plated zinc die castings. Die castings plated commercially with duplex chromium have shown only a few small blisters after 72 or 90 hr. of copper-accelerated salt spray. Up to 36 hr. exposure brought on a slight haze and light stain. In areas of low current density where the total thickness of the chromium was about 0.04 mil, a few small, dark spots appeared after 54 hr. The dark spots grew laterally and became unsightly during the next 36 hr. Figure 8 shows a magnified surface view after 90 hr. of the salt spray. The cross section, also in Fig. 8, shows that the dark areas resulted from lateral corrosion of the nickel under microcracks in the chromium and undermining and lifting of small flakes of chromium.

On die castings plated with more than 0.1 mil of duplex chromium, only a few, nearly microscopic, dark spots appeared, even when the duration in the copper-accelerated salt spray was extended to 144 hr. Thus, only a relatively slight change in appearance due to outdoor weathering is predicted for duplex chromium plate more than 0.1 mil thick applied over bright nickel plate.

Microcracks in duplex chromium are narrower than those in 0.4-mil (or thicker) ordinary chromium. The rate of movement of the cor-

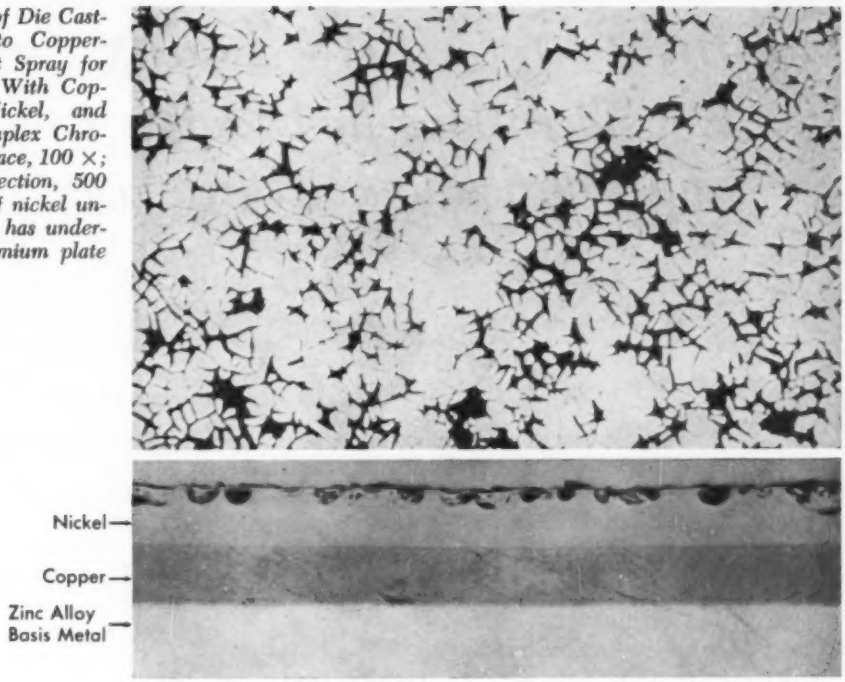


Fig. 8 — Views of Die Casting (Exposed to Copper-Accelerated Salt Spray for 90 Hr.) Plated With Copper, Bright Nickel, and 0.04 Mil of Duplex Chromium. Top: surface, 100 ×; bottom: cross section, 500 ×. Corrosion of nickel under microcracks has undermined the chromium plate

rosive media (and the corrosion products of the nickel) is restricted in the microcracks because of their narrowness. The action is additionally restricted by increasing the thickness of the chromium to more than 0.1 mil. This in turn lengthens the capillary path and improves the performance of the plating.

Work at Battelle has demonstrated that zinc die castings with composite coatings including any one of the improved electroplates compare favorably with buffed Type 302 and Type 430 stainless steel during exposure to accelerated tests. Better resistance to corrosion also has been observed for the electroplated zinc die castings after 14 months of outdoor weathering. Other die castings plated in accordance with old practices (Table I) appeared to show more corrosion than stainless steel.

The degree of improved durability in terms of prolonged life can be estimated conservatively at about 3 to 1 for a composite of duplex nickel and ordinary (0.01-mil) chromium compared with a composite of bright nickel and ordinary chromium, and about 8 to 1 for a composite of duplex nickel and 0.05 mil of crack-free chromium comparted to the bright-nickel-ordinary-chromium composite. Judging from accelerated corrosion studies, a composite of bright nickel and 0.15 mil of microcracked chromium should have about the same life as the composite of duplex nickel and 0.05-mil crack-free chromium.

Where do the improved plating processes stand today? Duplex nickel has already been widely adopted. Crack-free chromium has been introduced in several plants. Greater use of crack-free chromium to add to the improved performance obtained with duplex nickel is predicted. Research is expected to bring out further developments making it easier to adapt present-day chromium plating facilities.

Microcracked chromium will increase in popularity if research can show how to get good performance with a thickness of 0.05 mil or less where costs should be competitive with those for crack-free chromium. In plants that have not yet adopted duplex nickel, duplex chromium (greater than 0.1 mil) might be less costly to adopt than duplex nickel plus crack-free chromium.

At least another year of service data will be needed to determine if a composite of duplex nickel and 0.01 mil of ordinary chromium will satisfy automobile buyers. Two more years of commercial experience will be needed before the performance of composites of duplex nickel and crack-free chromium and of bright nickel and duplex chromium can be compared.

Columbium Alloys Today

Considerations in Design and Fabrication of Structures

*By L. P. JAHNKE, R. G. FRANK and T. K. REDDEN**

Work is progressing rapidly to develop data needed on properties of columbium alloys for elevated temperature applications. Tests show weldability to be excellent and coating systems indicate reliability. (Q-general, P-general; Cb-b, 17-51)

IN LAST MONTH'S *Metal Progress*, we discussed the general problems of alloy development in the columbium system and presented data on strength characteristics. In this article we will discuss further the properties of today's columbium alloys (Table I) with particular reference to design considerations.

Modulus of Elasticity

The elastic modulus of columbium is the lowest of the four refractory metals and this was of early concern to structural designers. Though an excellent property for reducing thermal stresses (especially when teamed with columbium's low coefficient of thermal expansion), a low modulus is a handicap when designing on stiffness criteria. Early data showed a rapid decrease of modulus with increasing temperature. These data are not accurate, although the

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Table I – Today's Columbium Alloys

NAME OR CODE	NOMINAL COMPOSITION	DEVELOPER OR PRODUCER	STATUS
FS-82	33% Ta, 1% Zr	Fansteel Metallurgical Corp.	Commercial
1% Zr	0.75-1% Zr	Widely studied*	Commercial
F-48	15% W, 5% Mo, 1% Zr	General Electric Co.	Pilot production†
F-50	15% W, 5% Mo, 1% Zr, 5% Ti	General Electric Co.	Pilot production†
D-31	10% Ti, 10% Mo	DuPont Co.	Pilot production
Cb-7	28% W, 7% Ti	Union Carbide Metals Co.	Laboratory
Cb-16	20% W, 10% Ti, 3% V	Union Carbide Metals Co.	Laboratory
Cb-65	7% Ti, 0.8% Zr	Union Carbide Metals Co.	Pilot production
Cb-74	10% W, 5% Zr	Union Carbide Metals Co.	Laboratory

*Alloys containing 0.75 to 1.04% Zr have been evaluated by most concerns working in this field. The alloy was originally discovered because of zirconium's occurrence in columbium ore and its carryover into the reduced metal.

†Alloys in pilot production have been arc melted in 4 to 6-in. diameter ingots and converted to bar and sheet. Mill products of General Electric's alloys have been produced for internal consumption.

figures still crop up. The best information shows a gradual decrease from 17,700,000 psi. at 70° F. to 15,600,000 at 1650° F.

Alloying can increase the elastic modulus appreciably, especially if the high-modulus refractory metals (tungsten and molybdenum) are added. Tests on F-48 alloy (15% W, 5% Mo, 1% Zr) show a modulus of 25,000,000 psi. at 70° F., and 21,000,000 psi. at 1650° F. This is nearly a 50% increase over unalloyed columbium.

The increasing familiarity of airframe designers with corrugated (or other stiffened) structures has made the elastic modulus of a material of secondary importance. However, to use such structures the metal must be amenable to joining. Fortunately, the properties of columbium promise that most of its alloys will be weldable by modern techniques. The few alloys which have been tried prove this is so, although a large range in weldability is encountered.

Table II – Ductile-to-Brittle Transition Temperature for Columbium and Molybdenum-Base Alloys

	Unalloyed Cb	FS-82	F-48	Mo With 0.5% Ti
Interstitial content				
Carbon	0.015	0.01	0.08	0.021
Oxygen	0.02	0.06	0.025	0.0015
Nitrogen	0.025	0.025	0.025	0.0003
Transition temperature				
Slow bend (1T)*	< 70	<70	<70	<70
Tensile†	−350	<70	<70	<70
V-notch Charpy	−200	—	250	700

*Room velocity 3 in. per min.
†0.005 in. per in. per min.

Ductile-Brittle Transition Temperature

As with all metals with a body-centered cubic structure, columbium and its alloys undergo a transition from ductile-to-brittle behavior at a temperature which depends upon the alloy composition and the test used. The sparse data available are given in Table II.

Pure columbium is very ductile even at extremely low temperatures. Alloying to improve strength raises the transition temperature considerably. It is interesting to note the relative tolerance of molybdenum and columbium to embrittlement by interstitial elements.

Fig. 1 – Oxidation Characteristics of Columbium Alloys Compared With Molybdenum at 2000° F. Table I gives composition of alloys

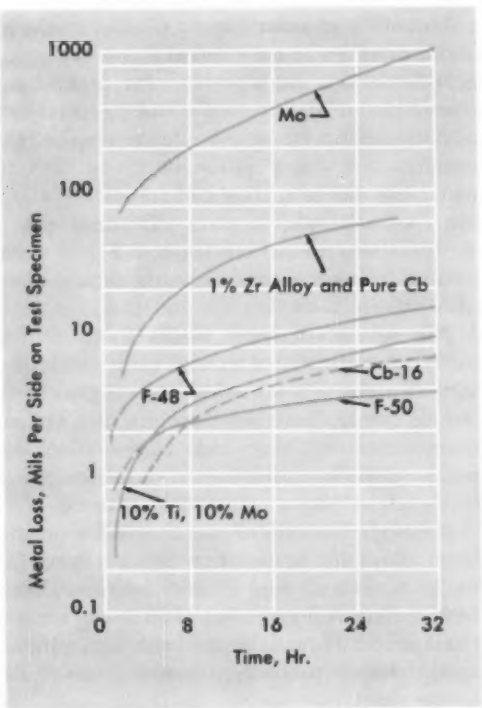
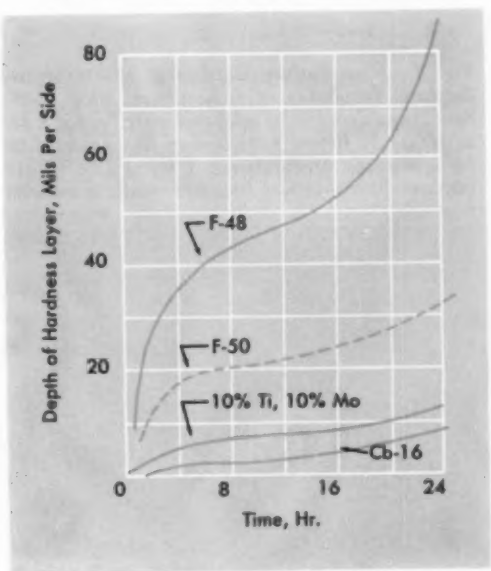


Fig. 2 – Subsurface Hardening of Columbium Alloys Due to Contamination From Heating in Air at 2000° F.



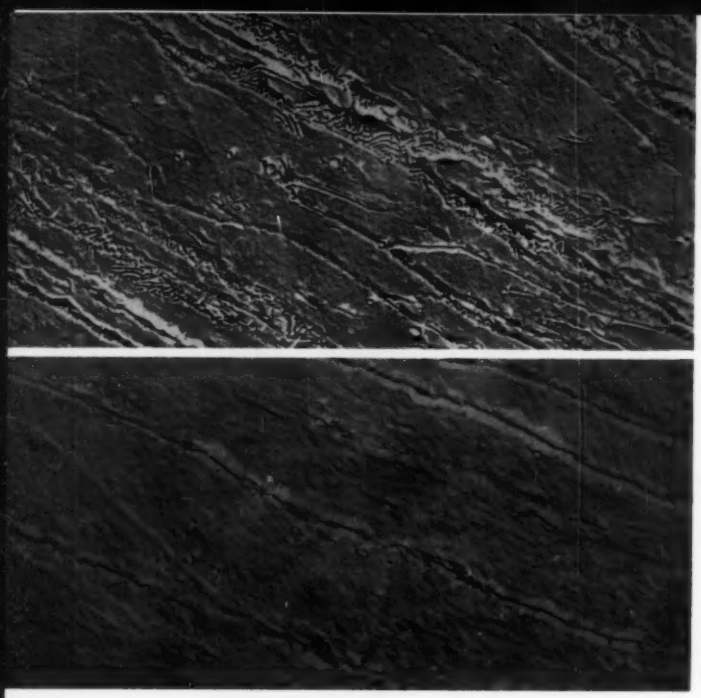
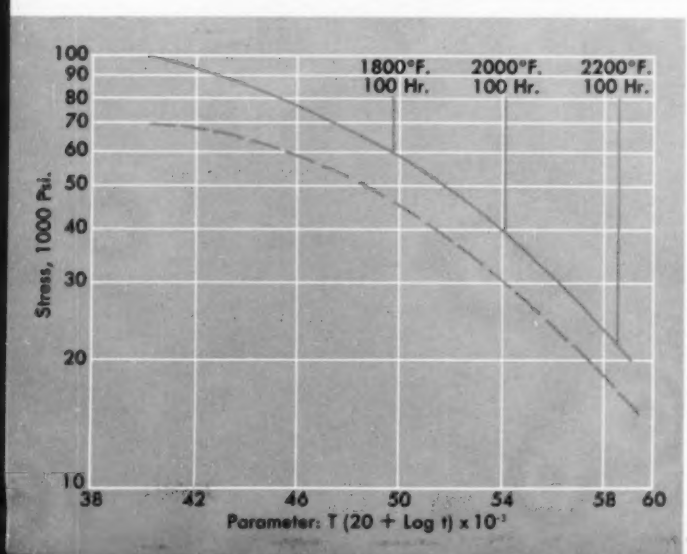


Fig. 3 – These Electron Micrographs of Columbium Alloy F-48 Show That Oxygen Diffusion at Elevated Temperatures Occurs Primarily Along Grain Boundaries. Specimen in top photo was exposed to air at 2000° F. for 5 hr. Bottom photo shows as-swaged sample. 6000 ×

Recrystallization Temperature

If strain hardening is relied upon as a strengthening mechanism, a considerable reduction in strength occurs as a result of recrystallization. For example, molybdenum alloys lose up to 50% of their strength when recrystallized, and it was expected that columbium alloys would react similarly. However, data on F-48 alloy show that almost complete recrystallization gives less than a 10% decrease in strength. This shows that this alloy obtains its strength primarily as a result of solid-solution formation and from dispersed particles.

Fig. 4 – How Surface Hardening Affects Stress-Rupture Properties of Columbium Alloy F-48. Specimens denoted by solid line were heated 1 hr. at 2000° F. before test; broken line shows data for specimens stress-relieved 1 hr. at 2200° F. in vacuum. Stress-rupture tests were made in vacuum



It is felt that other columbium alloys of this type will give similar results.

It is difficult to compare recrystallization temperatures of columbium alloys because of significant effects of processing variables and because of the different tests by which they are determined. Data which we believe comparable are given below for 100% recrystallization to an equiaxed grain structure from a heavily (70 to 90%) cold worked condition.

Alloy	Recrystallization Temperature
*Cb	1800 to 2000° F.
Cb, 1% Zr	2200
FS-82	2200
D-31	2200
F-50	2500
Cb-7	2500 (est.)
*F-48	2600 to 3000

*Recrystallization temperature decreases with lower interstitial levels. The ranges noted have been obtained.

Oxidation Behavior

The oxide of columbium (Cb_2O_5) melts at about 2700° F., so the existence of a molten or volatile oxide is not a problem for applications contemplated at this time. But the study of oxidation behavior of columbium-based alloys requires that consideration be given both to metal loss due to scaling and subsurface alloying with atmospheric gases. Figure 1 shows the oxidation characteristics and Fig. 2 gives data on "contamination" (subsurface hardening) of alloys in Table I.

The subsurface layer which forms during oxidation is brittle; it cracks easily, and thus acts as a sharp notch which may significantly reduce the load-carrying capacity of a columbium structure. Magnitude of this effect depends on the layer thickness and the toughness of the underlying uncontaminated metal.

Although the rate of metal loss for columbium alloys due to oxidation is much lower (20 to 300 times less) than for molybdenum alloys, both scaling and subsurface hardening are too rapid for the alloys to be used at a high temperature without protective coatings, except for a very short time.

Surface Contamination Effects

Because it is possible for failures to occur in coatings, it is of interest to study the effect of the surface contamination (embrittlement) on the mechanical properties of columbium alloys. The only data available are for F-48 alloy, but these describe the problem. Machined specimens were heated in air at 2000° F. to produce varying levels of contamination (Table III).

The data indicate that oxygen is mainly responsible for the hardening effect. Electron micrographs (Fig. 3) show that diffusion occurs primarily along grain boundaries in this alloy. Other data have indicated that additions of reactive metals, such as titanium, cause the diffusion to occur more uniformly through the matrix of the grains, thus markedly decreasing the depth of the subsurface zone, presumably through scavenging effects.

Tensile data on specimens heated for ½ hr. and 5 hr. (Table III) resulted in cleavage fractures below 1200° F. in both instances. Above 1200° F., significant strengthening and gradually increasing ductility were observed. A 25 to 30% increase in high-temperature strength can also be seen in the data on stress-rupture in Fig. 4. The creep rate at 2200° F. was decreased ten times by "contaminating" 34% of the original cross section.

Much more work must be done before these effects are adequately evaluated. There are obvious strength benefits from "oxygen-hardening" the surface, but the loss of ductility is serious and must be kept in mind when designing components for multiple missions.

Auto-Ignition

A phenomenon termed "auto-ignition" can occur with any metal when energy released by the oxidation reaction exceeds that lost by convection, conduction and radiation. With columbium and its alloys, ignition occurs only at fairly high mass flow rates of air at a temperature determined to a great extent by the surface-to-volume ratio of the specimen. When the conditions are right, oxidation rates become self-accelerating and catastrophic failure occurs. Thus, it has been necessary to study this phenomenon before considering certain applications for columbium and its alloys.

At mass flow rates of 1000 to 4000 lb. of air per hr. per sq.ft. of test area, the ignition temperature of columbium is about 2685° F. However, temperature of ignition for alloys has been

Table III – Rate of Contamination of F-48 Columbium Alloy Heated in Air at 2000° F.

Treatment	% Cross Section* Contaminated	Specimen Analysis	
		% O_2	% N_2
None	0	0.039	0.031
½ hr.	34	0.150	0.033
2 hr.	60	0.332	0.035
5 hr.	90	0.490	0.043

*Of 0.160-in. diameter bar.

lower – for example, 2620° F. for alloy F-48 and 2450° F. for F-50. These data are better understood by referring to Fig. 5.

Tests were also made on specimens of unalloyed columbium and F-48 alloy on which protective coatings with intentional defects had been applied. Auto-ignition was not evident here – even at 2800 to 2850° F. for 10 min. Thus, protective coatings decrease the possibility of auto-ignition, by effectively reducing the surface-to-volume ratio of the specimen.

Protective Coatings

The requirement for coatings on columbium alloys for structural applications at high temperatures is predicated on the need to prevent loss of ductility due to air "contamination" and to prevent auto-ignition. The reliability possible with columbium stems from the fact that small defects in the coating do not cause catastrophic failure as happens with molybdenum.

Coatings which have been developed for columbium include: *(a)* sealed, flame-sprayed

Fig. 5 – Auto-Ignition of Unalloyed Columbium. Tests show thermal response of metal in air flowing at 4000 lb. per sq.ft. per hr. Temperature stabilized in argon during "To" period, then changed to air at Time "0"

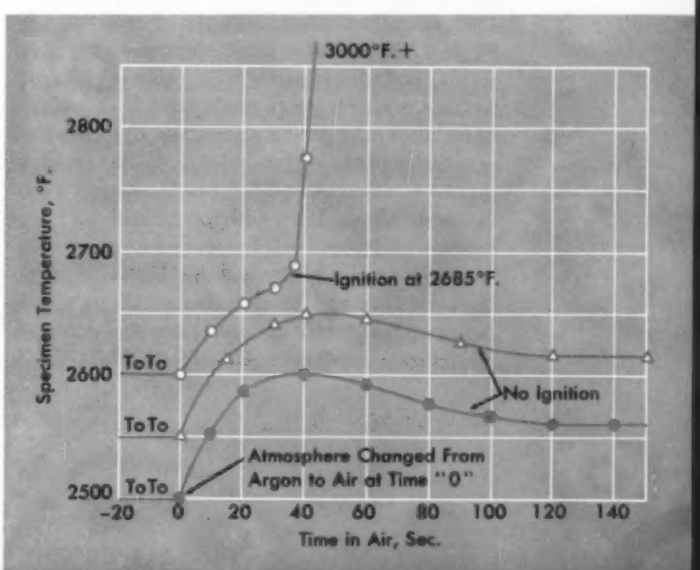


Table IV – Physical Properties of Columbium Alloys

Alloy	Melting Point	Temperature	Elastic Modulus (*a*)	Coefficient of Thermal Expansion (*b*)	Thermal Conductivity (*c*)	Specific Heat (*d*)	Density (*e*)
F-48	4500° F.★	70° F.	25	3.4	24★	—	0.34
		2000	18★	4.0	34★	—	—
F-50	4400★	70	24	—	20★	—	0.33
		2000	16.5	—	—	—	—
D-31	4100	2000	8.5	4.1	—	0.074	—
FS-80	4350	70	15.1★	—	32	0.065	0.313
FS-82	4550	70	16.5	—	—	—	0.366
Cb (unalloyed)	4480	70	15.1	—	30	0.065	0.313

★Estimated data
(*a*) Psi. × 10^6
(*b*) In. per in. per °F. × 10^{-6}
(*c*) Btu per sq.ft. per hr. per °F. per ft.
(*d*) Btu. per lb. per °F.
(*e*) Lb. per cu.in.

alumina; *(b)* hot dipped, liquid metal diffusion of aluminum or zinc; *(c)* solid-state or gas diffusion of silicon or chromium; *(d)* vapor deposition of silicon, chromium or alumina; *(e)* cold slurry dip of aluminum; and *(f)* electroplate of chromium.

The first three coatings are probably the most advanced and indicate excellent potential. For example, the sealed, flame-sprayed alumina coating will protect small columbium specimens for 30 min. at 3000° F. or protect for well over 1000 hr. at 2300° F. The main problems today are in applying the coating to large complex structures. Maintaining consistent quality is also of concern.

Weldability Is Good

Columbium, in contrast to molybdenum, has excellent weldability. This property results from its inherently good ductility plus its high tolerance for the interstitial elements, oxygen and nitrogen. A wealth of knowledge has been accumulated on both resistance and inert arc fusion welding of unalloyed columbium as well as for the weak but ductile alloys, such as the 1.0% zirconium alloy, 8.0% titanium alloy, Cb-65 and FS-82. The joint efficiency of fusion welds, and the shear tensile properties of resistance welded joints made in 1% Zr columbium alloy and FS-82 alloys are equivalent to properties obtained for stainless steel. In addition, it is possible to bend fusion welded joints in these alloys 180° without failure – an important consideration for complex structures.

Less is known of the welding behavior of the high-strength and more complex alloys. It is believed that the solubility of oxygen, nitrogen and carbon in alloys such as F-48, F-50, Cb-7, Cb-16, and D-41, which have high concentrations of tungsten and molybdenum, is lower than in unalloyed columbium. As a result, it is expected that weldability will be poorer. Resistance and fusion welding of F-48 alloy is now being investigated.

Methods for brazing columbium and its alloys are virtually nonexistent. It is generally felt that work in this area needs much more effort than is currently in progress.

It is characteristic of new metal systems that in the early years of alloy development only those properties which specifically relate to the application in mind at the time are obtained. It is only when an alloy of some potential emerges from the laboratory that it is worth the cost and effort to determine complete design properties. Columbium has reached this stage of development within the past year and as a consequence only limited data are available on the physical properties of the alloys. These data are summarized in Table IV.

Summary and Prognosis

This article and Part I which appeared in *Metal Progress* last month have summarized the salient results of a very few years of work on columbium. The much greater effort now under way promises to expand this knowledge quickly. Nevertheless it is valuable to stop occasionally and examine a field of technology during its growth – as has been done here. It appears to the authors that in columbium a metal system of truly major importance has been added to the engineering scene. Its potential has so far merely been touched lightly, but nowhere have monumental difficulties been encountered. The future promises much.

A New Fracture Test for Alloy Steels

*By D. L. NEWHOUSE and B. M. WUNDT**

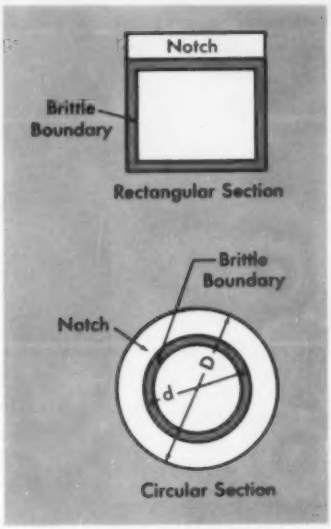


Fig. 1 – Cross Sections Showing Brittle Boundary in Circular and Rectangular Notched Specimens

Notched bar fracture tests, such as the Charpy V-notch impact test, can be modified to simulate important characteristics of large spin bursting tests. Fracture toughnesses and appearances similar to those of large notched disks were obtained from specimens which were nitrided to produce a hard brittle case. (Q26r, Q6; ST, 4-51)

INVESTIGATORS OF BRITTLE FRACTURE in large steel forgings have a big problem in reproducing the essential characteristics of such fracture in laboratory tests. These characteristics include a low nominal stress level and the virtual absence of fibrosity or ductility in the fracture. One solution to this problem is the use of bursting tests of large rotating notched disks. Tests of such disks were used* to obtain fracture toughness of steel, G_{co}. However, this method has drawbacks; it uses much material, is very expensive and therefore cannot be applied extensively in alloy steel development.

Other tests also have limitations. For example, slow bend tests on large notched specimens (3 sq.in., 20% deep notch, 0.005-in. root radius) correlate well with bursting test results, but like the bursting tests, they require much metal. Of course, the standard Charpy V impact test has been very useful. Correlations have been found between fracture strength and large disks and the 50% Fracture Appearance Transition Temperature (FATT)†. However, because of the small size of the specimen and the large radius of the notch (in relation to other dimensions), the side shear lips and fibrous "thumbnail" under the notch form a much larger proportion of the total fracture area than they do in large notch disk and slow bend test fractures. Because of this much greater boundary deformation (compared with large spin and bend tests), Charpy V specimens absorb too much energy. Therefore, they are not suitable for determining fracture toughness, G_{co}.

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*"Bigger, Better, and Sounder Forgings – Part II", by Ernest E. Thum, *Metal Progress*, September 1959, Vol. 76, p. 121-126.

†The temperature at which the area of cleavage fracture appearance is 50% of the original area under the notch.

The New Test

To fill this gap we have devised a new test which permits us to evaluate fracture toughness with small test specimens. Briefly, stand-

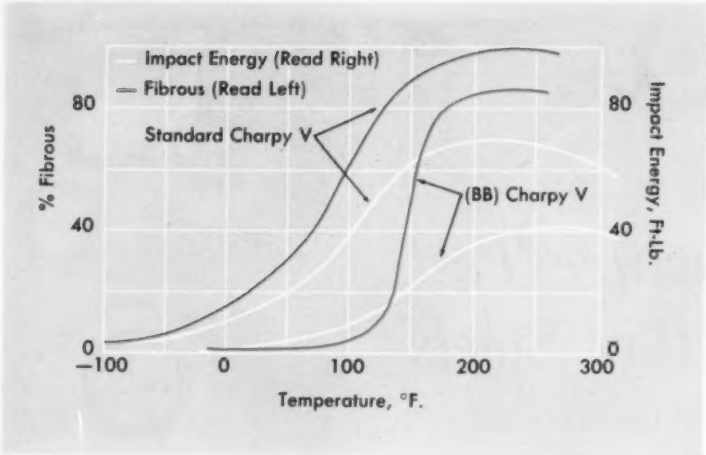


Fig. 2 – Plots of Impact Energy and Fracture Appearance Against Temperature for Standard Charpy V Impact Specimens Against Nitrided Brittle Boundary Impact Specimens From the Same Forging

ard Charpy V impact specimens are treated by nitriding*. This produces a very hard, brittle-behaving layer, completely around the circumferential boundary surface of the notched section. The temperature required for this method, 975° F., does not alter structure or properties of the Ni-Mo-V steel which we investigated. (Of course, steels subject to temper brittlement at 975° F. would need further treatment to avoid or remove embrittlement produced during nitriding.)

The brittle boundary has two effects. First, it reduces drastically the impact energy absorbed (apparently at all temperatures), and second, it raises considerably the brittle-to-ductile transition temperature as measured by either energy or fracture appearance criteria. Figure 2 presents results of tests on a Ni-Mo-V forging. At 75° F., the energy absorbed was reduced from 30 to 6 ft-lb., and the 50% FATT was increased by about 75° F. Also, the mode of fracture of the nitrided impact specimen in the transition range is radically altered. The fibrous "thumbnail" under the notch is greatly suppressed, and the shear lips, which are usually observed on the free surfaces, are completely absent. The fracture, whether its appearance is crystalline or fibrous, is completely framed in the crystalline fracture of the nitrided case. Figure 3 shows the fracture appearance of a standard Charpy V specimen and a nitrided specimen from the same location in a forging. Both were tested at 150° F.

*This technique can also be used for notched slow bend and notched tensile tests. The use of these tests and the necessary calculations for the determination of G_{co} from nominal fracture stress values are described in "Applications of the Griffith-Irwin Theory of Crack Propagation to the Bursting Behavior of Disks", by D. H. Winne and B. M. Wundt, *A.S.M.E. Transactions*, November 1958, p. 1634 to 1658 and "A Unified Interpretation of Room-Temperature Strength of Notched Specimens as Influenced by Their Size", by B. M. Wundt, A.S.M.E. Paper 59-MET-9.

Interpreting The Test

This drastic change in the fracture mode may be interpreted by assuming that the nitrided layer altered the boundary conditions for the fracture. Ordinarily, shearing deformation occurs at the *(Continued on p. 166)*

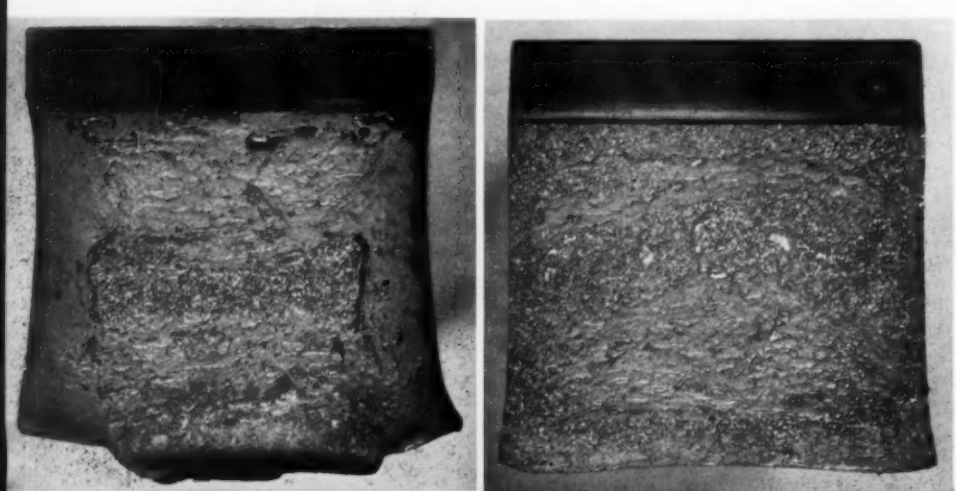
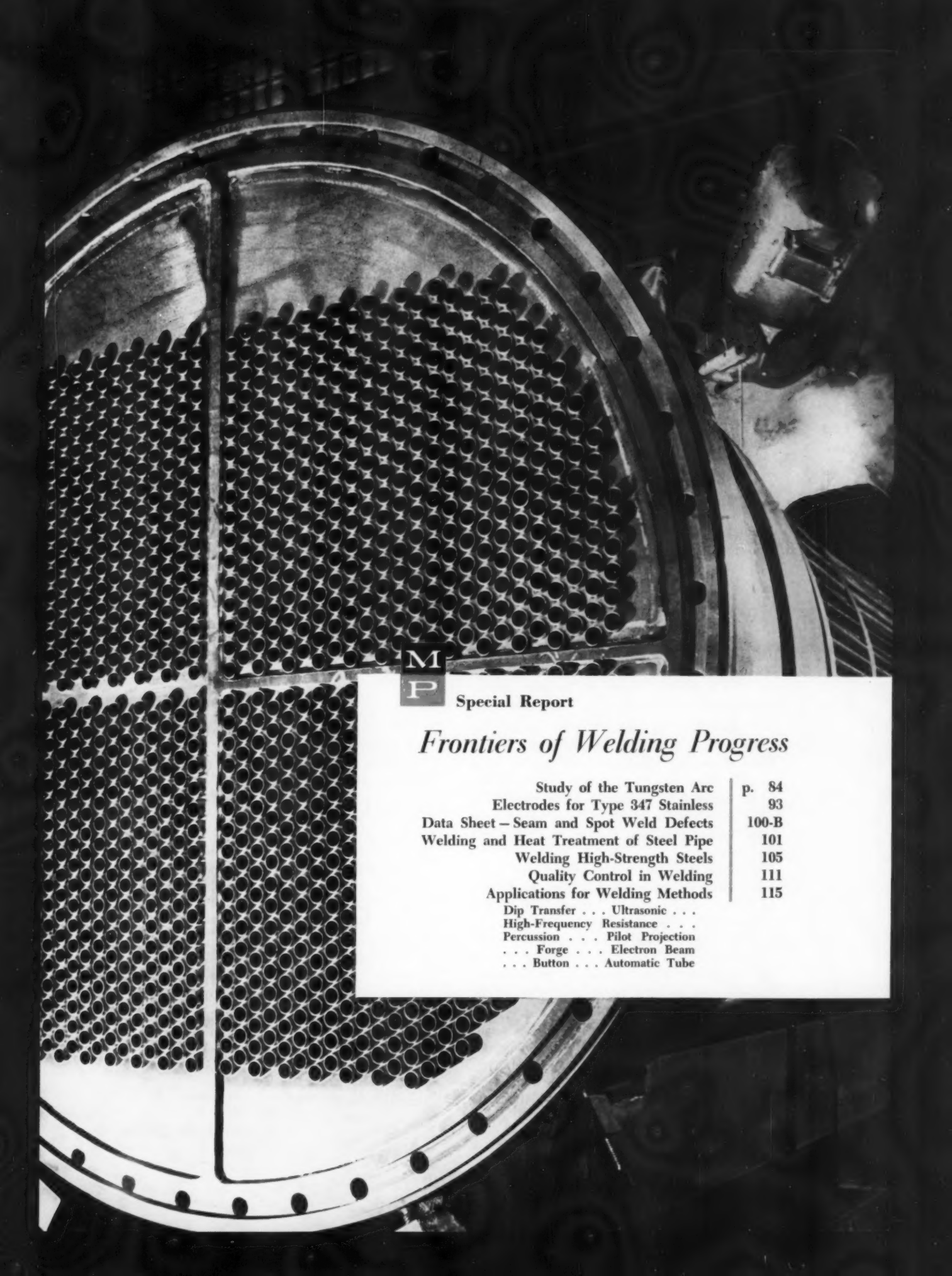


Fig. 3 – (Left) Fracture Appearance of a Normal Charpy V Impact Specimen (62 ft-lb.) and (Right) a Nitrided Specimen (23 ft-lb.), Both Tested at 150° F.



M P

Special Report

Frontiers of Welding Progress

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Frontiers of Welding Progress

A Fundamental Study of the Tungsten Arc

*By E. F. GIBBS**

Through a review of theory and a photographic study of tungsten arcs under various conditions, the basic relationships between tungsten electrode configuration and flame shape and voltage and current characteristics of an arc can be determined. Much of this fundamental knowledge can be applied to practical welding. (K1; W)

TUNGSTEN ELECTRODE CONFIGURATION is recognized as having a definite effect on arc flame shape and effectiveness in making good welds. The geometry of the tip can be altered to fit better into existing welding conditions. Also important for welds of good quality are edge preparation and the manner of flame impingement.

Just how these factors and others, such as arc blow, affect arc operation has been the subject of fundamental study at Boeing Airplane Co. A continuing effort, the study has as its primary aim the improvement of production arc welding practices by a better understanding of existing arc theory, supplemented by photographic investigation of arcs under controlled conditions. Basically, it has been shown that:

- The arc has two concentric zones — a central plasma and a surrounding flame. No inner zone of especially intense heat is evident.
- Argon and helium arcs which produce the same weld bead configuration have about the same wattages, although the voltages and currents required differ widely.
- Arc lengths at equivalent voltages on different metals vary significantly.
- At equivalent voltages, electrode tip configuration governs arc length. Greater arc lengths are associated with the more blunt electrodes.
- Blunt electrodes have lower operating and short-out voltages than sharp-pointed electrodes. Lower arc voltages may explain this.
- At equivalent voltages, the more blunt electrodes also project arcs of smaller diameter in argon gas but not necessarily in helium.
- The "arc-concentrating" effectiveness of blunt electrodes seems partly due to their ability

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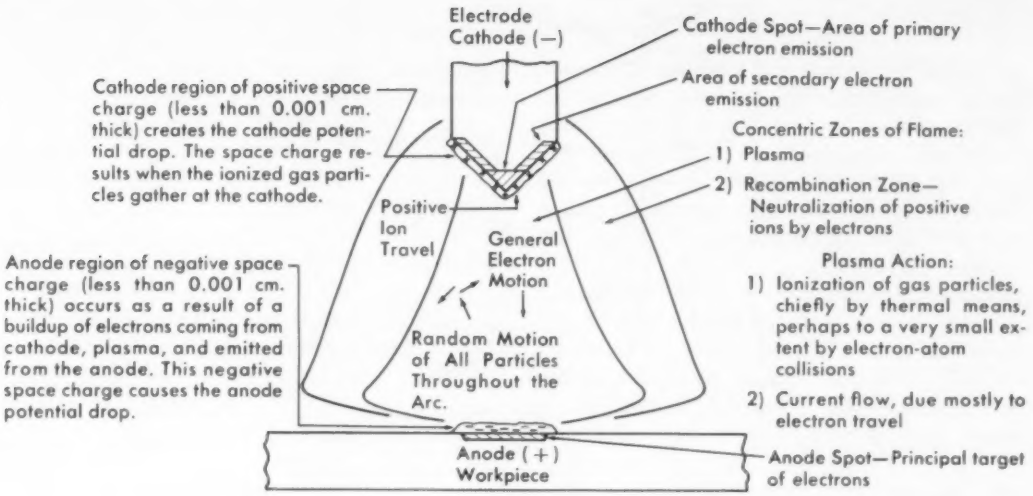
Electrode
Cathode (−)
Cathode Spot—Area of primary electron emission
Area of secondary electron emission
Concentric Zones of Flame:
1) Plasma
2) Recombination Zone—Neutralization of positive ions by electrons
Plasma Action:
1) Ionization of gas particles, chiefly by thermal means, perhaps to a very small extent by electron-atom collisions
2) Current flow, due mostly to electron travel
Cathode region of positive space charge (less than 0.001 cm. thick) creates the cathode potential drop. The space charge results when the ionized gas particles gather at the cathode.
Positive Ion Travel
General Electron Motion
Random Motion of All Particles Throughout the Arc.
Anode region of negative space charge (less than 0.001 cm. thick) occurs as a result of a buildup of electrons coming from cathode, plasma, and emitted from the anode. This negative space charge causes the anode potential drop.
Anode (+) Workpiece
Anode Spot—Principal target of electrons

Fig. 1 — Electrical Characteristics of a Straight-Polarity Arc

to operate at lower arc voltages than sharp-pointed electrodes.

- Blunt-tipped electrodes are more susceptible to arc blow. This may result in part because of tip shape, and is definitely affected by increased arc length for the blunt tips.
- Arc blow causes a slight increase in arc voltage.
- At the same voltage, the arc length seems to increase with the addition of filler wire.

Electrical Characteristics of the Arc

When an arc is started by touching the electrode to the workpiece and withdrawing it, the rapidly diminishing cathode contact area undergoes extreme heating accompanied by profuse electron emission. The emitted electrons are attracted toward the positively charged anode (Fig. 1) and raise the temperature of the shielding gas atoms through collisions with them. Repeated collisions of these extremely hot particles — atoms, electrons, and molecules — result in thermal ionization of some gaseous atoms. These positively charged gaseous atoms are attracted to the cathode surface, where their kinetic energy is converted to heat. This, then, is the source of heat that keeps the cathode hot enough for electron emission.

When an arc is started with a superimposed high-frequency current, the high-voltage spark jumps the gap and causes a small amount of gaseous particle ionization. As described above, the gas ions raise the cathode to emitting temperature and an arc is established. The presence of both positively and negatively charged particles is necessary in order that the gaseous column will conduct freely at welding voltages. Only a small fraction of the atoms present need be ionized.

If ions were completely absent, current flow could take place only under the influence of a high voltage, no matter how freely electrons might be supplied.[1]* Figure 1 indicates positive ion motion toward the cathode and electron motion toward the anode. There is also considerable lateral and otherwise random ion and electron motion throughout the arc because of collisions among the particles. Ions are said to have a short life; therefore, only those produced immediately outside the cathode will actually strike the cathode surface.

The bulk of the current flow is via electron flow rather than by the motion of positive ions, although the arc plasma contains equal concentrations of electrons and positive ions at any instant. However, the electron flow rate is much greater because the positive ions are simply too heavy to be accelerated rapidly. The continuous feeding of electrons into the welding circuit from the power source accounts for the constant balance between electrons and positive ions in the arc, regardless of the higher transfer speed of the electrons.

Cathode and Anode Spots

Figure 1 also shows several other areas of interest in the arc. The cathode spot is an area

*Numbers refer to bibliography on p. 92.

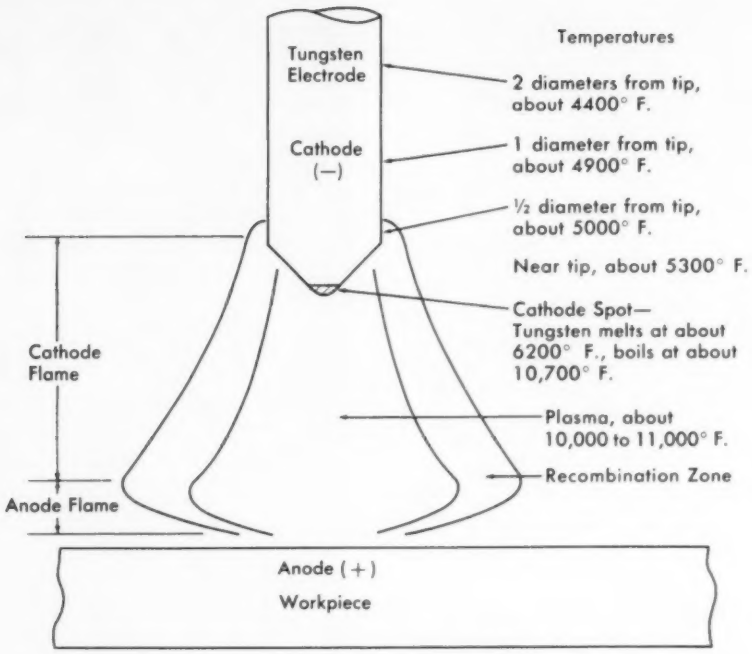
Temperatures
Tungsten Electrode
2 diameters from tip, about 4400° F.
Cathode (—)
1 diameter from tip, about 4900° F.
½ diameter from tip, about 5000° F.
Near tip, about 5300° F.
Cathode Spot—Tungsten melts at about 6200° F., boils at about 10,700° F.
Cathode Flame
Plasma, about 10,000 to 11,000° F.
Recombination Zone
Anode Flame
Anode (+)
Workpiece

Fig. 2 – Thermal Characteristics of a Straight-Polarity Arc. Sources of heat are at the cathode, in the plasma and at the anode. For short arcs (0.06 in. or less), the arc may show only the conical shape of the cathode flame

of thermionic emission, from which electrons are profusely "boiled out". Cathode spots on metallic electrodes are usually molten and are often boiling. On some metals the cathode spot will wander rapidly, possibly as a result of the stripping off of the emitting layer of atoms so as to expose a layer that is too cold to emit. Thus, the spot is forced to seek a hotter location. Wandering is often accompanied by sputtering of the cathode. This sputtering contributes to the deterioration of the point on permanent electrodes.

An area of secondary electron emission surrounding the cathode spot is also illustrated in Fig. 1. Secondary electron emission is a result of ion impact on the cathode surface, whereby electrons are dislodged. The remainder of the ion kinetic energy results in heating of the cathode, while some goes to heat loss to the surrounding atmosphere. Arcs from electrodes such as carbon and tungsten which have high melting points are supported mainly by primary electron emission. Arcs from copper and aluminum operate chiefly on secondary electrons. Iron and steel arcs are intermediate in nature.[2]

The anode spot on the workpiece in Fig. 1 is the principal target of electrons coming from the cathode and the plasma. These impinging electrons cause additional secondary electron emission from the anode.

Both the cathode and the anode have very thin space-charged regions immediately outside their surfaces. According to Spraragen and Lengyal[3], these thin space-charged regions cause the abrupt drop in potential at the surfaces of the cathode and anode.

An over-all view of the arc shows three axial zones and two concentric zones. The zones along the axis of the arc are the cathode region, the plasma or arc column, and the anode region. The concentric zones are the plasma region of thermal ionization and current flow, and the surrounding flame which constitutes the recombination zone wherein occurs the neutralization of positive ions.

Thermal Characteristics of the Arc

Figure 2 illustrates the thermal characteristics of the arc and the approximate temperatures of the tungsten electrode and the arc plasma. Electrode temperatures were determined with a micro-optical pyrometer in a 100-amp. argon arc.[4] They approximate tem-

peratures found in nearly any tungsten arc. (Electrode temperature will vary with current, however.) The plasma temperature has been estimated at 10,000 or 11,000° F. for most arcs.[5]

An arc can sometimes divide into two different flames if it is about 0.06 in. or longer. One emanates from the cathode and the other from the anode. The cathode flame makes up most of the flame length and in short arcs, only the conical-shaped cathode flame is usually visible. On increasing the flame length, the anode flame length increases very little since the cathode flame fills up most of the additional gap. The anode flame has a steeper voltage gradient than the cathode flame.

Sources of Heat

There are three principal areas of heat generation in an arc (Fig. 2). At the cathode, heat is produced by ionic bombardment and outgoing electrons, some of whose energy is returned to the cathode. Spraragen and Lengyal point out that an energy balance for heat production is created at the cathode by heat loss in the form of escaping electrons, heat conduction toward the water cooled collet, gaseous conduction and convection, radiation, and evaporation of cathode material.

Heat is generated in the plasma by collisions of electrons, ions, and neutral particles, while some heat results from neutralization of charged particles in the surrounding flame.

At the anode, the incoming electrons generate extreme heat by striking the anode surface and giving up the "heat of vaporization" acquired at the cathode. These electrons also have considerable kinetic energy from having been accelerated across the arc by the difference of potential. Although heat is evolved all across the arc by resistance to current flow, it is thought to be especially intense near the anode because of the steep voltage gradient of the anode flame. Partly for this reason and partly because of electrons "condensing" on the anode surface, it is estimated that the anode absorbs two-thirds to three-fourths of the heat liberated in the arc column.[5]

It would seem that the intense heat generated in the plasma would have a violent effect on the electrode and workpiece surfaces less than 0.001 in. away. However, it is proposed that these relatively cold metallic surfaces are thermally insulated from the plasma by the microscopically thin space charge regions, in which an intense energy flux occurs.[5]

Voltage Distribution

Each of the three zones arranged axially in an arc (the cathode region, arc column, and anode region) makes a separate and distinct contribution to the arc voltage. The space-charged regions immediately outside the cathode and anode have definite voltage drops and exhibit very steep potential gradients. In contrast, the arc column has a rather flat voltage-to-length ratio. In a straight-polarity arc having a length of 0.05 in. at 14 volts between a thoriated tungsten electrode and a copper anode, a cathode voltage drop of 6.2 and an anode voltage drop of 3 are typical.[5] The remainder of the voltage drop must be attributed to the plasma.

As the arc is shortened, the voltage contribution due to the plasma will gradually disappear, until at an arc length of very nearly zero the voltage may be assumed to be the sum of the cathode and anode drops of potential. An arc, if it is to exist at all, will have a minimum voltage established by the physical and chemical constants of the surrounding and participating media, mainly the cathode and anode metals.

Voltage drop in the plasma is due to the electrical resistance of the arc column, but the origin of the cathode and anode voltages is more complex. Formerly it was thought[5] that the drop in potential at the cathode must exceed the first ionization potential of the shielding gas (15.7 ev. for argon and 24.5 ev. for helium) in order to ionize the gas column. This theory was discounted when argon and helium arcs were seen to operate well below the respective first ionization potentials of the gases. A subsequent widely accepted theory for low arc voltages is that the ionization of gaseous atoms can occur by adding energy in stages, whereby the atom would be raised through successive "excited" states in the process of gaining enough energy to dislodge one or more electrons. These gradual additions result from collisions of electrons, atoms and molecules in the arc.[2]

A more recent theory[5] states that the cathode and anode voltage drops increase with the heat losses to the cathode and anode. In comparing the sum of the cathode and anode voltages of a typical arc with minimum voltages obtainable in practice, the theory seems plausible.

Electron Emission Affects Arc Performance

Ease of electron emission from a metal surface is gaged by how much thermal energy

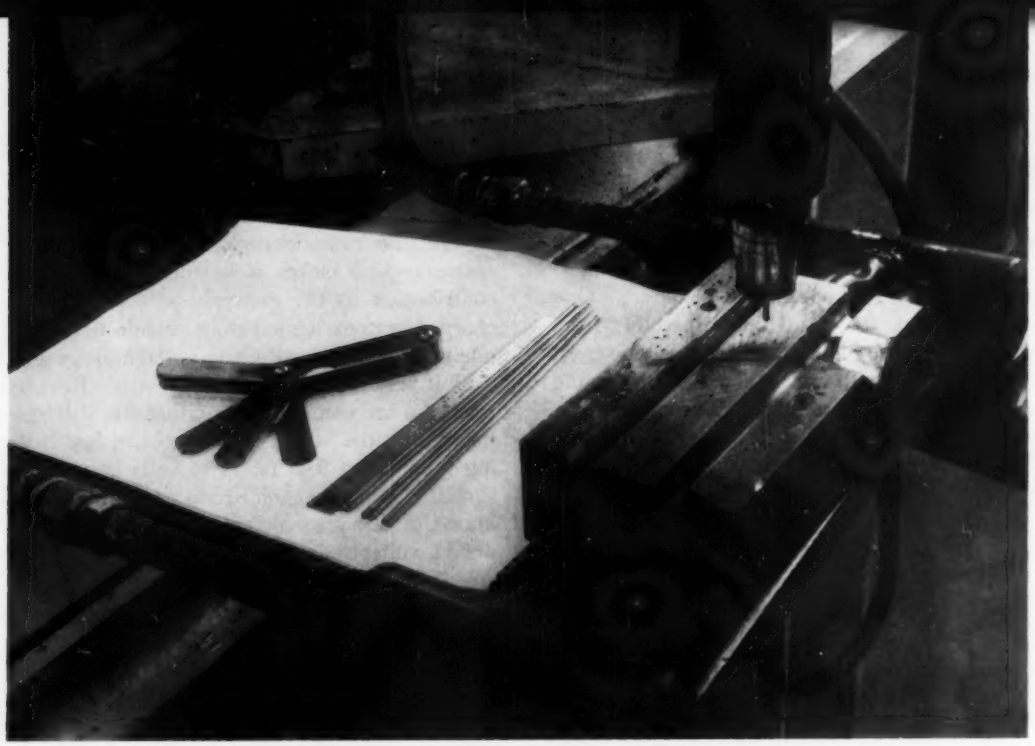

Fig. 3 – Equipment Used in Arc Study. Water cooled copper block permitted photographs to be taken of stationary arcs

must be added to an electron in that surface to enable it to escape. The escape energy of electrons from a metal is known as the thermionic work function. Metals commonly encountered as welding electrodes and workpieces all have about the same work function (about 4.5 ev.) The alkali earth metals have much lower work functions and the value for thorium (3.38 ev.) lies about halfway between the two groups. The significance of the work functions is that the alkali metals and thorium will provide electrons to the welding arc more profusely than will the more common welding metals. Hence, they have applications in welding. Sodium and potassium, for example, are used in the coatings of steel stick electrodes for manual welding. Sodium appears in sodium silicate used as a binder. It promotes electron emission and makes the arc more stable. Potassium, a more ready emitter than sodium, is used in electrodes for a-c. welding to promote stability in an arc which characteristically is extinguished and re-established 120 times per sec. A "softer" arc with a less harsh digging, penetrating action is obtained when emission is made easier.[2] Thorium is commonly used as an alloying agent in tungsten electrodes and can be expected to increase electron emission because of its low work function.

During arc operation, electron emission is thought to be accompanied by sporadic removal of a layer of metal atoms from the emitting surface, even on "permanent" tungsten electrodes.[6] Metallic ions may thus be expected to take a small part in the operation of the arc.

Experimental Work

The conditions selected for the study of d-c. straight-polarity tungsten arcs were intended to be representative of production welding conditions. The number of variables was trimmed accordingly to include the most significant features. Three electrode point configurations were taken as being the most common in production work. These included a point with a 20^{0} included angle, used for best arc stability, a point with a 90^{0} included angle, for more intense heat concentration, and one with a 180^{0} included angle (flat end), the extreme condition for heat concentration.

Photographs revealed that the electrode points being used were inaccurate as to point angle, and were often lopsided. Nonsymmetrical arcs were considered unsatisfactory for the arc study. Accurate symmetry and point angle were subsequently obtained by using a special fixture to hold the electrodes while they were being ground.

Figure 3 shows the principal experimental equipment used in the arc study. The water

cooled copper block served as the "workpiece" for obtaining most of the arc-length data and photographs. Some work was also done on 17-7 PH steel workpieces. Shown clearly are the four simulated joint conditions available on the copper block, namely, flat butt, V, bevelled U, and flat-bottomed U. The Linde HW-13 machine-mounted torch is in position over the copper block.

An electromagnet was used to induce arc blow for this study. It consisted of a soft iron core, 5/8 in. diameter by 5 in. long, having 90 turns of 16-gage insulated copper wire around it. Forty amperes from a d-c. welding power source were put through the magnet windings to create a disturbing field near the arc.

Arc Voltages and Arc Lengths

For the photographic portion of the arc study, it was usually necessary to let the arc burn in one spot for long periods of time during visual observation and camera adjustment. The arc could be expected to melt a deep crater or burn through a 17-7 PH steel plate if left in one spot for a very long time. For stationary arcs a water cooled copper block was used as the "workpiece". On the first attempt to get photographs of a 12-volt helium arc on copper, it was evident that the arc was shorter than a 12-volt arc on 17-7 PH steel. Some preliminary work was required to relate the voltages on copper and 17-7 PH steel to their respective arc gaps so that a more truly representative arc could be established for study.

Data were obtained so that several curves could be plotted showing the relation of voltage and arc length for the three principal electrode point configurations in helium and argon arcs operating on copper and 17-7 PH steel workpieces. To obtain each point, a 200-amp. arc was established, adjusted in length to give the desired voltage, extinguished and the resultant arc gap measured with a feeler gage. The crater-forming tendencies of the 200-amp. arcs on copper were considered slight but uniform and were neglected. For helium arcs, the craters were smooth-sided and about 0.005 in. deep. Argon arc craters were jagged in appearance and were about 0.007 in. deep except where small pinholes went deeper. Crater diameters were about 0.08 in.

Arc length measurements on 17-7 PH steel were obtained from traveling arcs, since crater forming beneath stationary arcs made stabilization difficult. Even so, wide, shallow craters

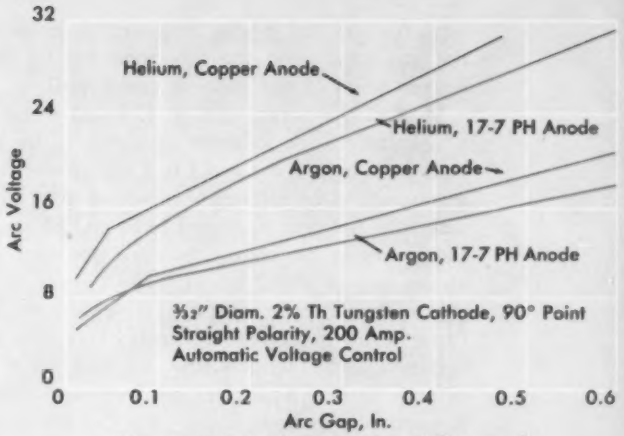

Fig. 4 – Relation Between Arc Voltage and Arc Gap During Automatic Voltage Control

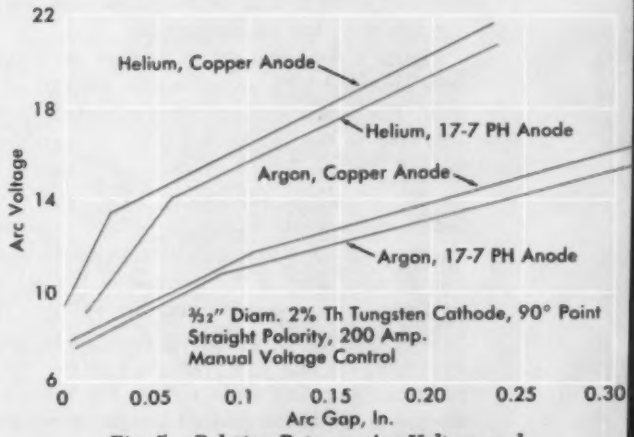

Fig. 5 – Relation Between Arc Voltage and Arc Gap During Manual Voltage Control

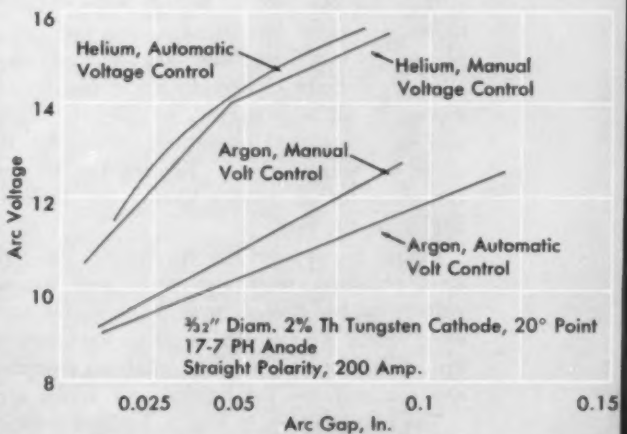

Fig. 6 – Relation Between Arc Voltage and Arc Gap Between Thoriated Tungsten Electrode (20° point) and 17-7 PH Steel. Sharp electrode points yield shorter arc lengths at constant voltage

were formed and it was necessary to measure the arc gaps from the electrode tip to the nearest point of the concave crater wall.

Most of the curves in Fig. 4, 5 and 6 show a definite change in slope at about 13 to 14 volts for a helium arc and 1 to 3 volts lower for argon arcs. One reference[7] mentions this characteristic, but only in regard to 50 and 85-amp. arcs, wherein the change in slope occurred at an arc gap of about 0.3 in. The change was said to denote the arc length at which the anode flame begins to increase noticeably and adds its voltage-length characteristic to that of the cathode flame. At shorter arc lengths, the arc is essentially cathode flame. For the 200-amp. arcs used in this study the change in gradient occurred at 0.025 to 0.060-in. length for helium arcs and 0.090 to 0.11 in. for argon arcs, varying also with the anode material.

Figure 4 depicts a set of voltage-arc length data obtained with an automatic voltage control. The points are somewhat scattered, probably due to the arc having been extinguished just as the machine had overcompensated in making a voltage adjustment. Figure 4 does not depict a sharp change in voltage gradient, also probably due to imprecision in maintaining the voltage. Part of the purpose of Fig. 4 was to determine respective operating voltages for helium and argon arcs having the same arc gap. However, the plot was found to give too low a practical operating voltage (8 to 8½ volts) for the argon arc in the desired arc gap range. It was necessary to select that voltage with the aid of Fig. 5.

Data for the plot in Fig. 5 were obtained under the same conditions as for the Fig. 4 plot except that the voltage was adjusted manually. A definite change in slope can be observed in all four curves. A slightly higher and more practical operating voltage for the argon arc was obtained. Figures 4 and 5 contain data for electrodes having 90° included angles on the tips.

Figure 6 compares the arc lengths and voltages obtained with automatic and manual voltage control on helium and argon arcs operating with a 20° included angle on the electrode tip. The plot also helps to establish comparative arc voltages for helium and argon arcs.

The curves given in Fig. 4, 5 and 6 indicate that the arc lengths with copper are shorter than the 17-7 PH steel arc lengths for the same voltages. This phenomenon agrees with theory according to the following reasoning: It has been stated that the cathode and anode voltage drops increase with the heat losses to the cathode and anode.[8] An anode metal of high thermal conductivity (consider copper compared to steel) provides a steeper thermal gradient from arc plasma to anode interior. Hence, there is faster heat flow and more heat loss to the anode. If the anode voltage drop is increased and constitutes a larger proportion of the total arc voltage, there is less voltage to be devoted to the plasma, therefore a shorter plasma length and a shorter arc length.

Effect of Electrode Point Configuration

Figure 5 compared to Fig. 6 indicates that the sharper electrode points have shorter arc lengths for the same voltages. The 180° electrode tip (flat end) has the longest arc gap for a given voltage in helium of any of the electrode tip configurations used. In argon, the electrode with a 90° tip gave shorter arc gaps than either the 20° or 180° tips.

For further studies, one weld setting was selected for helium-shielded arcs and one for argon-shielded arcs. For 17-7 PH steel, the representative conditions included an arc current of 200 amp. at 12 volts and helium flow of 100 cu.ft. per hr. A tungsten electrode 3/32 in. in diameter and containing 2% thorium was used with a No. 10 round torch cup and ⅜-in. electrode extension below the cup. To produce the same arc length on copper, it was necessary to increase the arc voltage to 14 volts.

The argon arc weld setting derived was intended to be the equivalent of the 12-volt, 200-amp. standard arc mentioned above; that is, it would produce an equivalent weld at the same travel speed on 17-7 PH steel. For this purpose the standard argon arc conditions were set at 280 amp., 9¼ volts, and 35 cu.ft. per hr. argon flow. The electrode was the same as that for helium. A No. 6 round torch cup was used. As with the helium arc, the argon arc voltage had to be increased to maintain the same arc length in changing from a 17-7 PH steel workpiece to a copper workpiece. The wattages of the helium and argon arcs which accomplish the same melting job do not differ greatly.

Photographs Reveal Arc Features

In the photographic portion of the study, color pictures of the arc operating under controlled conditions were obtained. To observe the zones of the arc, one photograph each of the helium and argon arcs were obtained. The

standard arc conditions previously described were used, except that the arc voltage was raised to 18 for helium and 14 for argon because it was thought that the increased arc length would better show the axial zones.

The three axial regions of the arc as described earlier are not discernible in photographs because the space-charged regions that are the cathode and anode zones are microscopically thin. Only the plasma is visible. No especially intense central areas were apparent. The bell-shaped cathode flame constitutes the major portion of the arc. The anode flame is saucer-shaped and is usually short. The confluence of the two flames is at the largest diameter of the plasma. All photographs of the arc operating on a flat surface illustrate the above described configuration. (Cover photograph illustrates an arc on 17-7 PH steel.)

Electrode Point Affects Arc Characteristics

Several arc operating characteristics are illustrated by the photographs of arcs emanating from the three most common electrode tip configurations. At equivalent voltages, the more blunt electrodes project smaller diameter arcs; in argon arcs the 20° angle electrode tip fans the arc out more on flat plate than does the 180° angle tip; the arc from the 90° angle tip is intermediate in diameter. The argon arcs in the various edge preparations generally show an increase in flame size with sharper electrode points. At present, it is not understood why the helium arcs do not have the same characteristic.

In both helium and argon arcs, the more blunt electrodes have larger arc gaps for the same voltages. In some of the photographs, the 20° angle tips seem to be nearly in contact with the workpiece, the 180° angle tips are well above the plate, and the 90° angle tips in general operate at arc gaps of intermediate length. A corresponding trend was noted in obtaining the minimum operating voltages for electrodes having the three different tip shapes.

The relation between tip angle and minimum operating voltage on copper with helium shielding are: 20°, 11½ v.; 90°, 10 v.; 180°, 9½ v.; with argon the values are: 20°, 9¼ v.; 90°, 7¾; 180°, 9 v. Minimum operating voltages on 17-7 PH steel (traveling arcs) in helium are: 20°, 11 vi; 90°, 9½ v.; with argon: 20°, 9 v.; 90°, 8 v.

The more blunt electrodes operate with more volts per inch of arc gap and can usually reach lower arc voltages, although not shorter arc gaps, before shorting out.

Consider the effect of groove shape on flame utilization. The photographs reveal that for any of the electrode tip angles the arc is more concentrated in a V-groove than in the other edge preparations or on a flat plate. However, in any but water cooled copper V-groove, the actual groove shape formed immediately ahead of the arc will be similar to the bevelled U-groove. The flat-bottomed U-groove yields a flame shape similar to that on a flat plate.

Blunt-tipped electrodes are thought to have an inherent ability to concentrate the arc for deep, narrow melting, as for a root pass in edge-prepared heavy material. This study reveals that the arc-concentrating effectiveness might be partly due to the ability of the blunt-tipped electrodes to operate at lower arc voltages than sharp-pointed electrodes.

Arc blow for the photographic study was induced by placing the end of the magnetic coil 1 in. from the arc. As has been noted before, the blunt electrodes, compared to the pointed electrodes, yield a larger arc gap for the same voltage. Photographs indicate that severity of arc blow increases with bluntness of electrode or with increasing arc gap.

In general, arc blow can be diminished by decreasing the arc voltage as well as by sharpening the electrode point. However, it should be kept in mind that decreased voltages are not as readily used with sharp-pointed electrodes.

Apply Theory in Everyday Welding

It is an accepted maxim that a tungsten electrode used in a direct-current reverse-polarity arc will carry only about one-third to one-half the current that it will in a straight-polarity arc. As is pointed out, the anode receives the bulk of the heat generated in a direct-current arc. In a reverse-polarity arc, the electrode (as anode) is receiving more heat than the workpiece, hence its reduced capacity for arc current. Tungsten electrodes in alternating-current arcs are between direct-current straight-polarity and direct-current reverse-polarity electrodes in current-carrying capacity.

Arc voltage is not dependent solely on the length of the arc, but varies also with the current. Figure 7 depicts the volt-ampere characteristics of a helium and argon arc. The two curves are similar in shape and show little variation in voltage in the more common welding ranges, 100 to 300 amp. In the lower current ranges, the voltage increases rapidly with decreasing current. In establishing operating arc

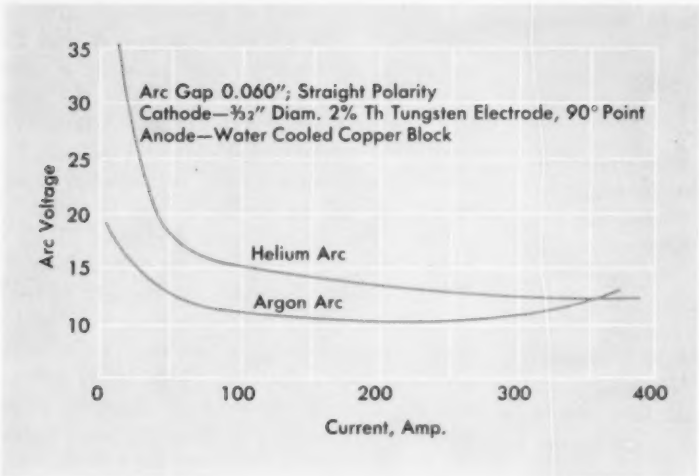

Fig. 7 — Arc Voltage and Current Characteristics of Helium and Argon-Shielded Straight-Polarity Arcs at Constant Arc Length. Electrode melted at 400 and 375 amp. in helium and argon shielding, respectively

lengths and voltages for thin-gage applications requiring low current, it is helpful if this volt-ampere feature is recognized.

In the first part of the volt-ampere curve, the decreasing voltage with increasing amperage is thought due to increased conductivity of the arc. The thin, low-current arc loses more heat per unit of volume and in doing so probably promotes thermal ionization less readily. This could account for higher voltages. As the current is increased the arc becomes fatter, assumes a lower surface-to-volume ratio, loses less heat per unit of volume, and is more conductive.[2] The voltage remains fairly constant over a wide range of current, then increases again at very high amperages. This voltage increase is attributed to an increase in average length of current path as the arc thickens and changes from cylindrical to spheroidal shape with increasing current. In Fig. 7 the argon arc shows a voltage increase at high amperages, but the helium arc does not.

Blast Cleaning Action

In the d-c. arc, the cathode undergoes a cleaning action which results in the removal of a surface layer of material. This is thought mostly due to the bombardment of the cathode by ionized gas particles or gas atoms in excited states which have been attracted to the cathode and which release their energy of excitation on striking.[2] Also, electron emission is often accompanied by removal of the outer layer of atoms from the cathode spot, although if this comprised part of the cleaning action it would do so only in a small way.

In straight-polarity welding, the cleaning action on the electrode has no value, but in reverse-polarity welding the action on the workpiece is useful in that it removes any adhering oxide film. With aluminum or magnesium, whose oxides are difficult to melt and which form rapidly after a preweld cleaning operation, the action is particularly valuable in inert-gas-shielded welding. The same blast cleaning action on the cathode is also useful in a-c. welding, as the workpiece is the cathode on the negative half-cycle.

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Frontiers of Welding Progress

Electrodes for Welding Type 347 Stainless

*By THOMAS J. MOORE**

A ten-year study of techniques for welding columbium-stabilized 18-8 stainless has derived information whereby a correct choice may be made from among five electrode compositions depending on the temperature, surroundings and other conditions of service. Certain heat treatments are to be avoided since they promote rapid corrosion even of these "stabilized" compositions. (W29h, K9r, Q27, R-general, 2-60, 2-62; SS)

WELDING OF COLUMBIUM-STABILIZED 18-8 stainless steel (Type 347) has always presented a problem, especially in heavy sections. A fully austenitic weld deposit is extremely hot short, and consequently infested with microfissures. A change in chemistry to give a small amount of ferrite produced a sound weld; the ferrite appeared to strengthen the cooling weld deposit and did not appreciably decrease corrosion resistance. When, however, the power industry started using stainless alloys for steam piping, to accommodate high temperatures and pressures, the commercial welding electrodes containing ferrite were found wanting, since they seriously embrittled during exposure to temperatures higher than 1000° F. because the ferrite transformed to the sigma phase.

As noted in the box entitled "History and Credits" (p. 95), a joint program to study this problem had been underway in the late 1940's by International Nickel Co. and Arcos Corp., prior to the appointment of the Welding Research Council's subcommittee and the start of Atomic Energy Commission's contract No. AT-(30-1)1233. One of the first activities of the new group (1952) was to survey the experience of 23 American fabricators of stainless steel equipment. They reported extensive cracking in weld metal which could be divided into four categories: *(a)* crater cracks, *(b)* star cracks, *(c)*

*Research Department, Arcos Corp., Philadelphia. Secretary, Subcommittee (of High Alloys Committee of Welding Research Council) on the Welding of Stainless Steel.

Fig. 1 – Typical Cracking in Segmented Circular Groove Specimen. Root of weld is a circle 2 in. in diameter

microfissures and hot-short cracks, and *(d)* root cracks. In the light of these circumstances the test program was directed toward finding one or more weld metals for Type 347 that conformed to as many as possible of the following requirements:

1. Freedom from weld metal cracks.
2. Suitability for applications in corrosion resisting equipment.
3. Freedom from embrittlement when exposed to elevated temperatures either during heat treatment or in service.
4. Suitability for uses requiring both strength and resistance to high temperature.
5. Suitability for very low temperature service, on the order of −300° F.

Enough work had already been done to show that any reasonable program of preheating or postheating could not prevent hot cracks, and that the easiest way to correct them would be to use weld metal with higher proportions of ferrite. This, however, would have some objectionable features–notably embrittlement in service. Another approach involved the careful control of the alloying elements in the electrode which tend to produce hot cracking and also those which tend to inhibit it. In this regard, fully austenitic welds should also be scrutinized.

For such reasons attention was addressed at first to the then conventional electrode, a Type 347 analysis giving a deposit containing 7% ferrite, and two analyses modified by high carbon and high manganese, respectively, giving fully austenitic welds. At the start of the work there was a serious columbium shortage and

Table I – Weld Metal Tested at High Temperature

Weld Deposit Composition	Electrode Type	Approximate Analysis of Weld Deposit
A	Type 347	19 Cr, 9 Ni, Cb (7% ferrite)
C	High-carbon 347	19 Cr, 13 Ni, Cb, 0.12 C (austenitic)
F	Low-carbon 308	19 Cr, 10 Ni, 0.036 C (4% ferrite)
H	High-manganese 347	19 Cr, 13 Ni, Cb, 5 Mn (austenitic)
16-8-2	Modified Type 316	16 Cr, 8 Ni, 2 Mo (4% ferrite)

History and Credits

By F. W. DAVIS

Difficulties in the welding of Type 347 stainless and defects appearing in heavy welded equipment led the High Alloys Committee of the Welding Research Council to appoint a subcommittee in March 1950 to review some promising work that was being conducted by International Nickel Co. and Arcos Corp. The subcommittee was later asked to prepare a comprehensive program of research on the welding of Type 347 stainless steel which might be sponsored by the High Alloys Committee. The members of this subcommittee were V. N. Krivobok, chairman, R. D. Thomas, Jr., M. A. Scheil, W. O. Binder, R. B. Gunia and A. L. Schaeffler, secretary. Such a report was presented in October 1950.

At the next High Alloys meeting in March 1951, it was noted that the shortage of columbium had developed so rapidly that little was available for other than military applications. It was recommended that the outlined program be postponed until a better appraisal of the supply of columbium could be made.

Directly after this meeting, F. W. Davis of the Division of Reactor Development, U. S. Atomic Energy Commission, proposed that if the subcommittee would direct the program the necessary funds would be contributed by the Commission. Davis was made a member of the subcommittee and the program started. Further changes in the subcommittee have included the addition of William B. DeLong, the replacement of Secretary A. L. Schaeffler by, first, Lorin K. Poole and, later, by Thomas J. Moore. On the decease of Chairman V. N. Krivobok, R. B. Gunia was appointed in his place. At present the members of the Advisory Subcommittee are R. B. Gunia, chairman, W. O. Binder, H. C. Campbell, F. W. Davis, W. B. DeLong, C. R. Mayne, M. A. Scheil, R. D. Thomas, Jr., R. D. Wylie, and T. J. Moore, secretary.

The present report summarizes nearly a decade of intensive work and is published now because the studies have achieved their original aim – to determine electrodes, welding techniques and post treatments which will produce sound, strong and corrosion resistant joints for high-temperature service.

Much credit is due to the companies listed below for the materials and services which they have provided gratis to this A.E.C.-sponsored program:

E. I. du Pont de Nemours & Co., Inc.
International Nickel Co.
A. O. Smith Corp.
Babcock and Wilcox Co.
Electro Metallurgical Co. (Union Carbide Metals Co.)
United States Steel Corp.

hence a noncolumbium extra-low-carbon variety of electrode was simultaneously evaluated. In more recent times a new composition suggested by the Babcock and Wilcox Co., namely 16% Cr, 8% Ni, 2% Mo (16-8-2), was examined in a brief series of tests beginning in 1956. (This electrode, for joining heavy sections of Type 347, has been publicized extensively. It produces weld metal containing about 4% ferrite.)

Evaluation of Chemical Composition

Our early studies of the cracking tendencies of Type 347 weld metal were summarized in "Statistical Analysis of Effects of Various Elements on the Crack Sensitivity of Fully Austenitic Type 347 Welds", printed in *Welding Journal*, Research Supplement, 1957, p. 442-s. The test specimen is shown in Fig. 1. Welding was done manually with lime-coated electrodes. This admittedly introduced the human factor; nevertheless a statistically valid relationship between cracking and chemical composition was established. Chemical analyses of the weld beads were computed from the analyses of electrode and base metal, taking into account dilution by the latter. The equation with coefficients given by a Univac computer is as follows: Per Cent Cracking = 133.6 + 6.44 ÷ C + 43.1 ÷ Mn + 1.8 Si + 384 S + 2295 P + 9.98 Ni − 4.48 Cr − 28.8 (Cb + Ta) − 487 N where C, Mn . . . represent the percentages by weight of the corresponding elements.

This equation looks funny, for it could readily give cracking greater than 100% for a *pure*

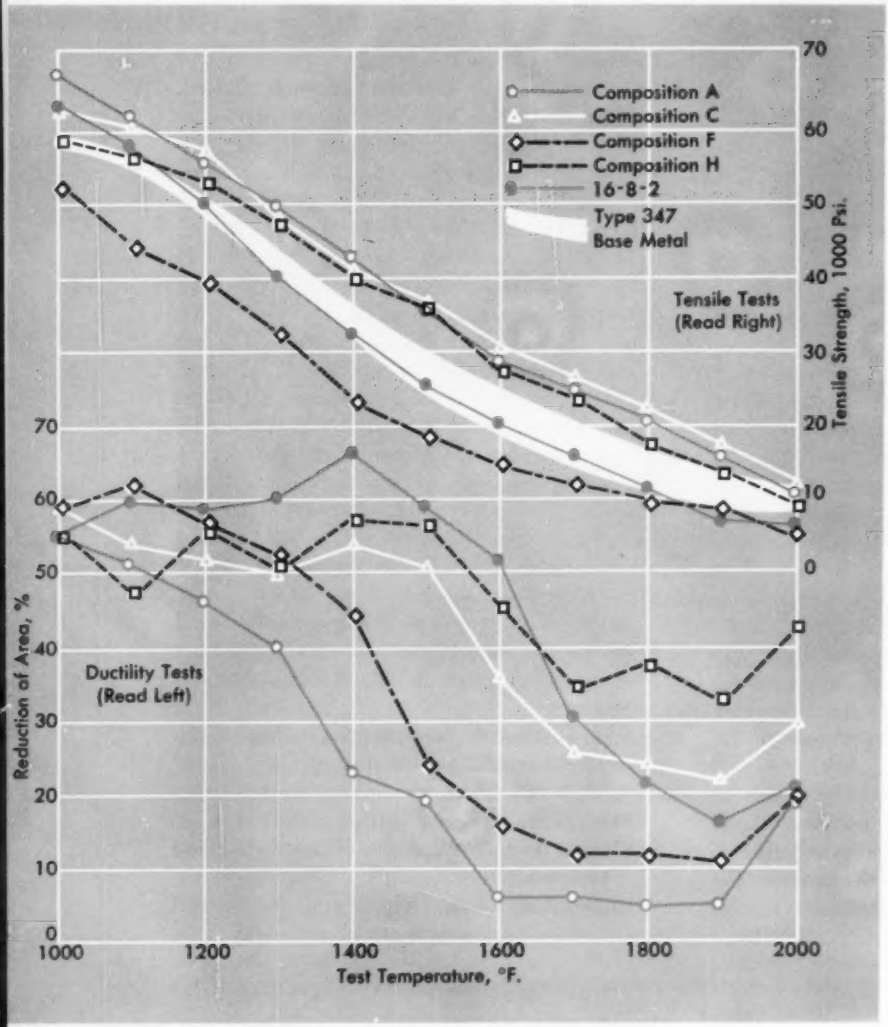


Fig. 2 – Tensile Tests on All-Weld-Metal Specimens at High Temperatures. Figures for elongation have approximately the same relationships as those for reduction of area, except that 16-8-2 has a much more pronounced peak between 1300 and 1600° F.

chromium-nickel alloy. However, it must be remembered that it applies only to commercial alloys of the 18-8 variety with normal variations in incidental or added elements; it should not be extrapolated to a theoretical Fe-Cr-Ni alloy. As a matter of fact, badly cracked specimens have cracks extending into the bead from the junctions between plates, in addition to circumferential cracking in the center of the weld bead. Since the "per cent cracking" is figured as the extent of cracking along the circumference of the 2-in. circle, cracks extending from the junctions between plates add to the total crack length and may result in cracking of more than 100% of the circumference.

When comparing the actual and the computed amount of cracking in a large number of these tests, the agreement was close—the difference in the standard deviation was 8 percentage points. The results may therefore be summarized as follows:

As carbon was increased from 0.062 to 0.104%, the cracking was diminished 42 percentage points. Increasing manganese from 1.31 to 4.13% had the effect of decreasing cracking by 22.4 percentage points.

For every 0.10% increase in silicon, cracking increased less than 0.2 percentage points.

For every 0.010% increase in sulphur, cracking increased 3.8 percentage points.

For every 0.010% increase in phosphorus, cracking increased 23.0 percentage points.

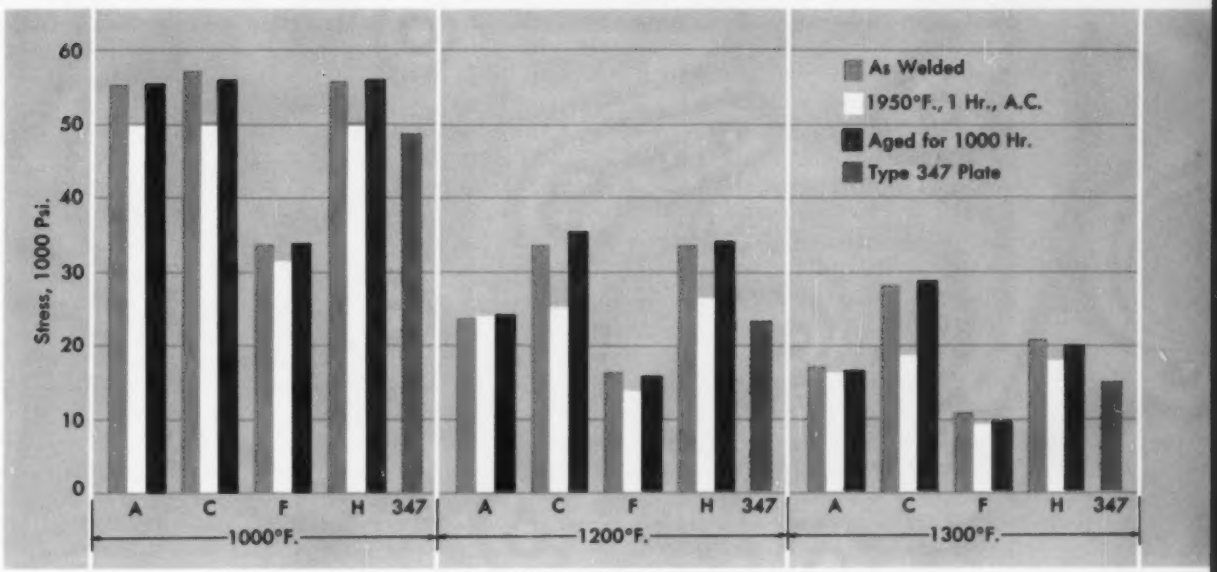


Fig. 3 – Stress for Rupture in 1000 Hr. at 1000, 1200, and 1300° F. for Compositions A, C, F, H All-Weld-Metal and Type 347 Base Material

As indicated by the equation, increasing the nickel has a detrimental effect, while more chromium, columbium and nitrogen are helpful. In the electrodes and welds studied, however, the range of these elements is small.

Because of the many approximations and assumptions which were introduced, no claim is made by the subcommittee for numerical accuracy of the mathematical equation. However, the qualitative relationship of the various elements on weld-bead cracking can be the basis for sound conclusions. Two promising, fully austenitic, modified Type 347 weld metals, one containing 0.12% carbon and the other containing 5% manganese, were accordingly selected for further study at elevated temperature.

Tests at High Temperature

Five electrodes giving five weld metal compositions judged to be the most promising for high-temperature service were then selected, as shown in Table I.

Tensile tests at elevated temperature were made at 100° intervals between 1000 and 2000° F., and results are shown in Fig. 2. The relationship of tensile strengths did not change in this temperature interval. Ductilities of Composition H (austenitic high-manganese 347) and of the new 16-8-2 were well retained up to 2000° F.; Composition C (austenitic high-carbon 347) was next best.

The curves for reduction of area in Fig. 2 indicate that the high-manganese Type 347, the new 16-8-2, or (to a lesser extent) the high-carbon Type 347, would be an improvement over the standard partially ferritic Type 347 electrode – at least as far as improved tensile ductility at elevated temperatures is concerned.

Stress-to-rupture in 1000 hr. at three temperatures and three conditions was also determined for all-weld-metal specimens of Compositions A, C, F and H. Results are shown in Fig. 3, which also includes comparison figures for a commercial Type 347 plate as noted in A.S.T.M. Special Technical Publication No. 124 (1952).

These stress-rupture tests generally indicate that for temperatures between 1000 and 1300° F., any of the Type 347 electrodes (Compositions A, C, or H) are suitable for joining Type 347 stainless steels since all are stronger than the base material. Specimens which had been aged 10,000 hr. prior to testing gave further evidence that such welds were stronger than the Type 347 base plate. Annealing for 1 hr. at 1950° F. followed by air cooling generally improves the rupture ductility of the columbium-bearing welds, particularly at 1200 and 1300° F., without seriously reducing the stress-rupture figure.

The low-carbon 308 weld metal containing

4% ferrite (Composition F) is much weaker than Type 347 base material in both the as-welded and aged conditions. Its ductility at high temperatures, as shown in Fig. 2, is measurably higher than standard Type 347 weld metal (Composition A). Weld metal which is deposited with standard Type 347 electrodes and contains 7% ferrite is inherently low in tensile ductility between 1500 and 2000° F. when loaded at standardized strain rates and its strength is considerably above that of Type 347 base material under the same conditions. Thus, in annealing heavy sections it is recommended that the heating rate be rapid between 1100 and 1925° F. to minimize the chance that a time-dependent, stress-rupture type of cracking may occur in the coarse-grained base material immediately adjacent to the weld.

In order to get some idea of the conditions which exist in the vicinity of an arc weld made in 1.5-in. stainless steel plate, not preheated, some hot ductility tests were conducted on all-weld-metal specimens at Rensselaer Polytechnic Institute using the method devised there* wherein test pieces are heated to 2400 or 2450° F. in a few seconds and immediately cooled to test temperatures. Specimens may be tested either on the heating or the cooling cycle. Results are summarized in Fig. 4.

The good ductility shown in the Rensselaer test for the partially ferritic Type 347 and 308 L welds (Compositions A and F) confirms the good resistance of these weld metals to hot cracking. The fully austenitic weld deposits, Compositions C and H, behaved rather poorly — that is, they were slow to recover ductility on cooling from 2400 or 2450° F. However, in various qualification tests these electrodes had been found to be practical, usable compositions in production-type welding of stainless.

16-8-2 Electrode — For welding heavy sections of Type 347 the 16-8-2 electrode would

*See "Further Studies of the Hot Ductility of High-Temperature Alloys", by E. F. Nippes, W. F. Savage and G. Grotke, Welding Research Council Bulletin No. 33 (February 1957).

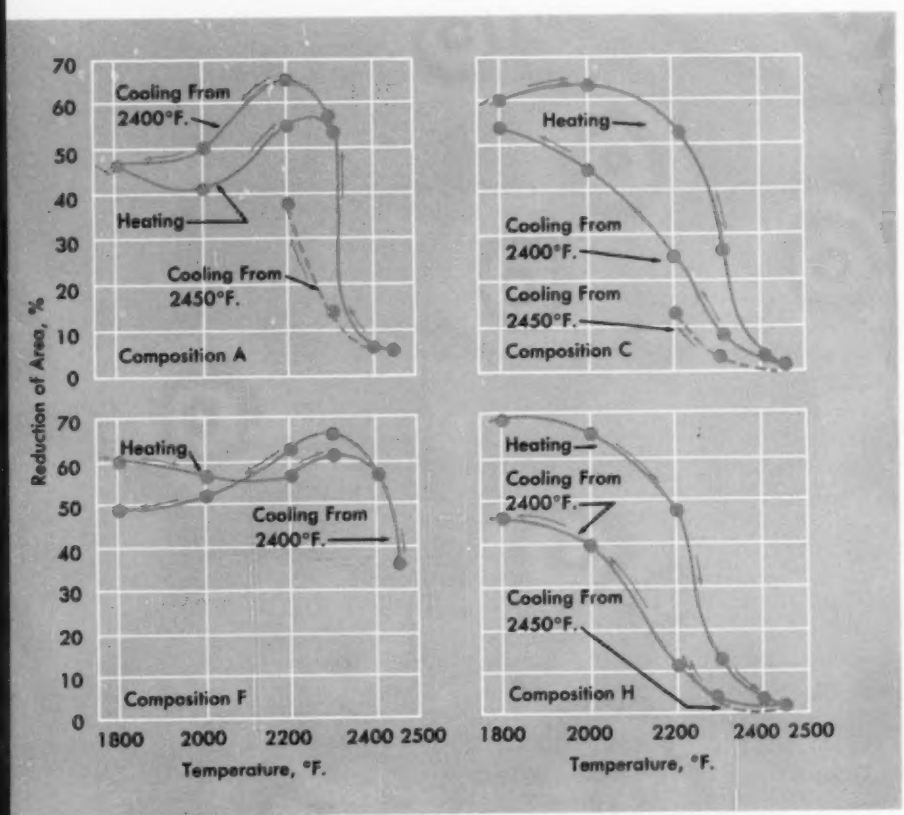


Fig. 4 — Hot Ductility Tests by the Rensselaer Polytechnic Institute's Method

have an advantage over the columbium-bearing welds, since the tensile strength of the 16-8-2 weld at temperature is slightly below the Type 347 base material and it possesses relatively good ductility in the range of 1800 to 2000° F. (See Fig. 2.) This would assure that minimum stress concentrations would occur in the heat-affected zone during welding and annealing, since the 16-8-2 weld is weaker in the annealing temperature range and has a capacity for plastic flow which would tend to relieve any peak stresses which would occur.

On the other hand, the 16-8-2 electrode is not recommended for use in applications where intergranular corrosion resistance is a service requirement. The analysis is not "stabilized", but is rather a modified Type 316. A second item which should be considered is Emerson and Jackson's observation* concerning the mode of cracking in some laboratory tests of circumferential welds in Type 347 pipe made with 16-8-2 electrodes. These authors found that the very capacity for plastic flow at elevated temperatures (as compared with the more rigid Type 347 pipe) may cause distortion and cracks to initiate from the *inside* surface.

Corrosion Resistance

Small rectangular samples (all-weld-metal) were cut from the middle of welds in ½-in. plate, as sketched in Fig. 5, and subjected to two standardized corrosion tests, namely the Huey test in boiling nitric acid and the acidified copper sulphate test. Parallel work was done on Compositions A, C, F, H and also on two other modified Type 347 weld metal compositions. All the weld metals appeared to behave as would be expected; the presence of a small percentage of ferrite did not appear to be objectionable. Acceptable corrosion rates (0.025 in. per year) were obtained for all these compositions in the as-welded condition and after heat treatment at 1550° F. or higher. Probably the most striking discovery in these corrosion studies was the fine performance of the columbium-free extra-low-carbon alloy (Composition F). This, too, was not wholly unexpected although its superiority had not been previously recognized.

However, one new and unexpected result

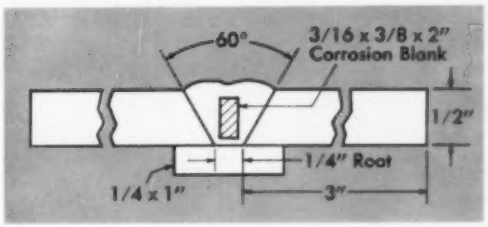


Fig. 5 – Sketch Showing How an All-Weld-Metal Test Piece of Composition F (Low-Carbon 308) Is Cut From a Butt Weld in 304 L Plate

was obtained, namely, the poor corrosion resistance after exposing all-weld-metal specimens in the as-deposited condition in the range of 900 to 1100° F. for a long time. These alloys were all of a "stabilized" type; thus, it was alarming to discover high corrosion rates, since these conditions might well be encountered in certain high-temperature processing equipment. H. F. Ebling and Merrill A. Scheil (a member of our Advisory Subcommittee) conducted similar studies on commercial sheet of Types 304 L, 316 L, and 347 and reported the results to the 1958 meeting of the Atomic Energy Commission's Welding Forum†. They found the same result – namely that the corrosion rate in the Huey test depends greatly on the time and temperature of heating in the 700 to 1500° F. range. For example, disastrous corrosion rates of 1 in. per year or more result if these steels are heated 5000 to 10,000 hr. at 950 to 1000° F. Prior "stabilization" by heating 2 hr. at 1650° F. does not correct this behavior in Types 304 L or 316 L, but does have a beneficial effect in Type 347 material.

To investigate this new corrosion phenomenon, we concentrated our studies on the 308 L weld (Composition F) since it had the best behavior in the initial tests. The results of these nitric acid corrosion tests are summarized in Fig. 6, plotted as a time-temperature-sensitization diagram, as suggested by Ebling and Scheil. Notice the extremely high corrosion rates which result from aging fairly short times (100 hr. or more) at the lower temperatures (800 to 900° F.). It may be generally concluded that as the aging temperature decreases from 1800 toward the 800 to 1000° F. range the peak corrosion rate increases, and second, the time required to reach the peak corrosion rate in-

*"The Plastic Ductility of Austenitic Piping Containing Welded Joints at 1200° F.", by R. W. Emerson and R. W. Jackson, *Welding Journal*, Research Supplement, 1957, p. 89-s.

†Published in *Metal Progress*, July 1959, p. 94, and August 1959, p. 87.

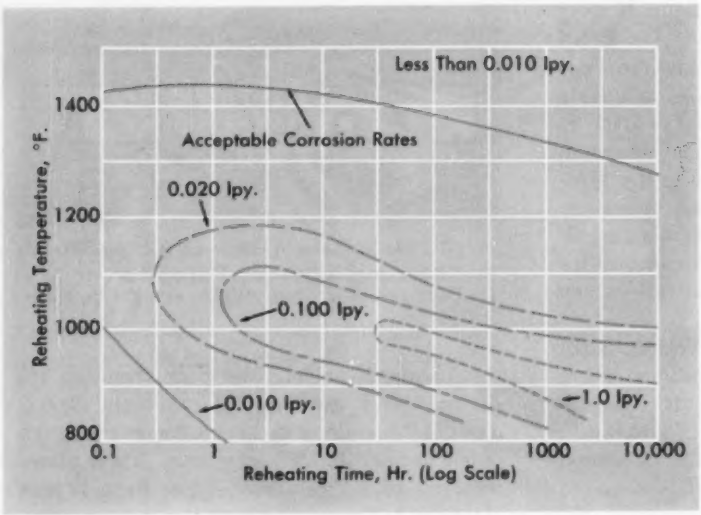


Fig. 6 — Time-Temperature-Corrosion Diagram for Low-Carbon Type 308 (Composition F) Weld Metal. Maximum corrosion rate observed (1.5 ipy.) was after heating 5000 hr. at 850° F. Chemical analysis: 0.036% C, 0.7% Mn, 18.5% Cr, 10.6% Ni, 0.05% N, 3% ferrite

creases with decreasing aging temperature. Long times at low temperatures (800 to 1100° F.) sensitize the welds to an alarming degree — 50 to 60 times as much as the conventional sensitizing heat treatments of 1 or 2 hr. at 1200° F. The curves of Fig. 6, by the way, assume the general form of the TTS diagrams derived by Ebling and Scheil and indicate the not surprising conclusion that stainless weld metal and base metal of similar types are "sensitized" by similar heat treatments.

In this connection the effect of carbon content was also investigated and, as was expected, the general level of corrosive attack increased with increasing carbon content. Whereas 1000 to 4000 hr. at 900° F. will induce an attack of over 1.0 ipy. in Type 308 weld metal with 0.036% C, this was substantially reduced by cutting the carbon content to 0.026% (and increasing the chromium to 19.7%). It would appear therefore that even at 0.026% carbon you may be in trouble if the service temperature is 800 to 900° F.

The effect of stabilizing heat treatments prior to aging was also investigated for Composition F weld deposits. Figure 6 shows that if 308 L analysis is heated for almost any time at 1200° F. and higher the expected corrosion rate will be lower than 0.025 ipy. Consequently, stabilizing heat treatments of 8 and 12 hr. at 1200° F. and 8 hr. at 1300° F. were investigated. The samples were subsequently aged at 1000° F. and subjected to the Huey test. The specimens which were heat treated at 1200° F. for 12 hr. had acceptable corrosion rates for aging periods of up to 1000 hr., but the other heat treatments were not effective in reducing severe corrosive attack. In fact there has not yet been discovered a suitable stabilizing heat treatment to avoid the extremely high rates of corrosive attack on Types 308 and 308 L weld metal which has been aged in the vicinity of 900° F.

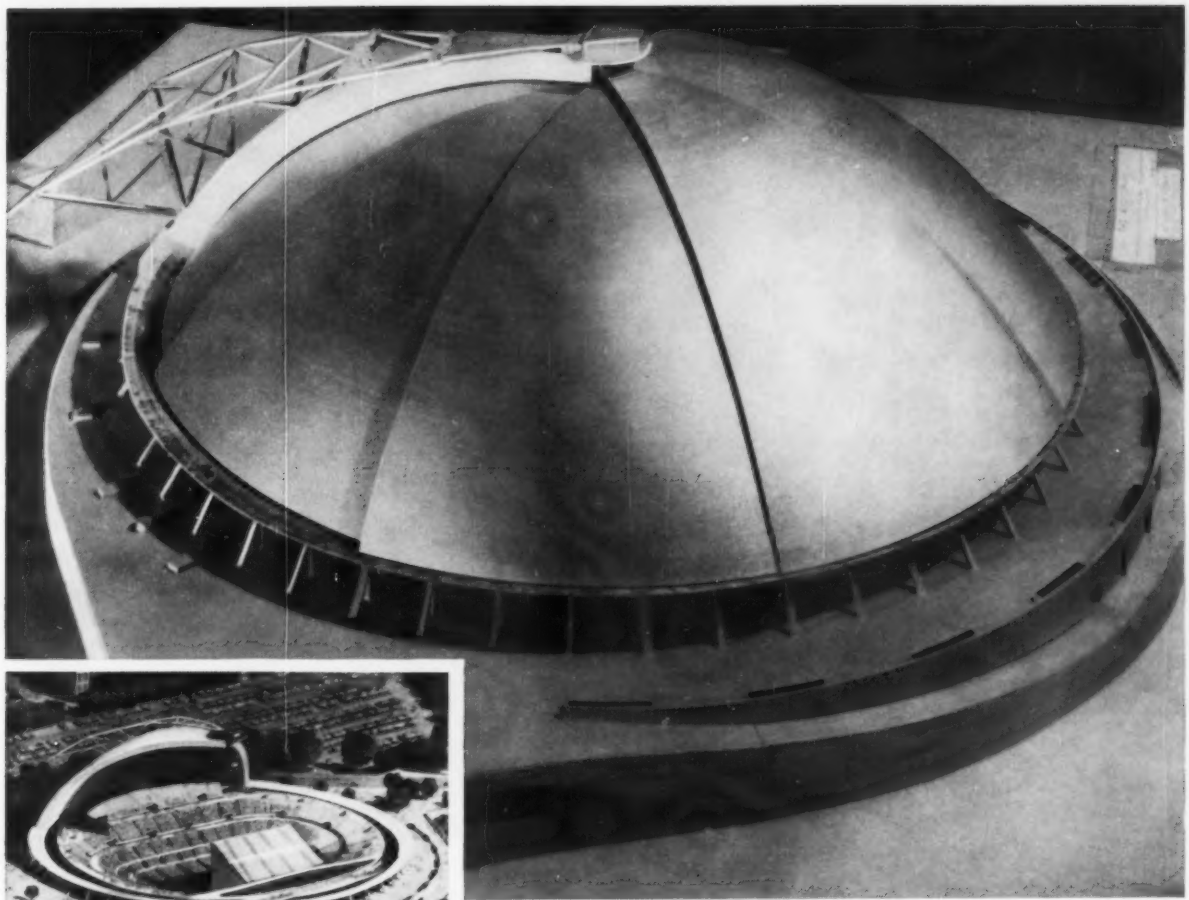
Weld Metal High in Nitrogen

Welds from the high-nitrogen Cr-Ni-Mn (Type 204 L) core wire were investigated briefly. The electrode was covered with a standard lime coating. It seems to have promising possibilities for equipment to serve at high temperatures.

Analyses follow (ferrite was 0 to 1% by Severn ferrite indicator):

	Electrode	Weld
Carbon	0.029	0.047
Manganese	9.44	7.15
Silicon	0.65	0.47
Sulphur	0.012	0.013
Phosphorus	0.020	0.018
Chromium	17.40	18.00
Nickel	6.29	6.09
Nitrogen	0.19	0.22

Room-temperature tensile properties of the weld metal were excellent. Stress-rupture tests indicated that its strength is similar to that of Type 347 weld metal and is above Type 347 base material at 1200° F. Thus, it appears that this composition may be suitable for electrodes to join Type 347 stainless steel. However, there is one fly in the *(Continued on p. 162)*



All-weather auditorium in Pittsburgh will be covered by a 415-foot diameter Nickel-containing stainless steel dome. Largest of its kind in the world, the dome will protect an audience of more than 13,000.

"Push-button umbrella roof" of stainless steel gives Pittsburgh a new all-weather auditorium

Watching a play or listening to music under the stars heightens the enjoyment. That is, until a passing shower comes along to wash out the fun. But now comes a new idea in auditoriums. In this one, an umbrella roof of Nickel-containing stainless steel will close at the first drops of rain—and on with the show.

It's a simple concept, but a daring one. Eight huge sections nest together when the dome is open. Push a button, and six of these sections glide quietly together around an outside track.

They looked into all sorts of sheathing materials in designing the dome before choosing stainless – a Nickel-containing stainless steel.

For stainless with Nickel in it is one of the most weatherproof metals there is. It is corrosion-resisting all the way through – in salt air as well as industrial atmospheres. What's more, it's virtually self-cleaning – rainfall alone keeps this metal clean.

No wonder you see Nickel-containing stainless wherever strength, long life and handsome appearance are called for! Not only in buildings – inside and out – but everywhere you look.

Suggest something to you? Can stainless help you solve a problem involving corrosion, stress, appearance, temperature extremes? The way to find out is to write us. We'll see if Nickel-containing stainless steel – or some other nickel alloy – may be just what you're looking for.

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street INCO New York 5, N. Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Circle 453 on Page 48-B

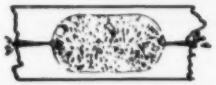
Weld Defects in Austenitic Stainless; Cause and Cure

Ideal Nugget

Unbalanced Nugget
- Misalignment of electrodes
- Off-center dressing of electrodes

Undersize Nugget
- Insufficient current
- Insufficient "on" time
- Excessive electrode force

Surface Expulsion
- Electrode too sharp
- Excessive current for electrode force
- Foreign matter on surface
- Insufficient coolant on electrodes

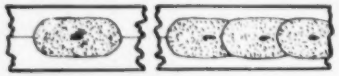


Excessive Expulsion at Interface
- Insufficient electrode force
- Excessive current or "on" time
- Electrode too sharp
- Foreign matter at interface

Concave Sides on Nugget
- Insufficient "on" time
- Insufficient current
- Insufficient width of electrodes

Lack of Tangency or Overlap
- Insufficient current
- Excessive "off" time or roll speed
- Insufficient "on" time

Cracks in Parent Metal
- Insufficient electrode width
- Electrode too sharp
- Excessive current or "on" time
- Insufficient "off" time
- Excessive roll speed
- Insufficient electrode force



Void in Nugget
- Insufficient electrode force
- Excessive current or "on" time
- Electrode too flat
- Insufficient "off" time
- Excessive roll speed

Cracks in Nugget
- *Vertical cracks with voids*
- Excessive current or "on" time
- Insufficient "off" time
- Insufficient electrode force
- Electrode too flat

Cracks in Nugget
- *Horizontal cracks in center*
- Insufficient electrode force
- Insufficient "off" time
- Electrode too flat
- Excessive current
- Excessive roll speed

Cracks in Nugget
- *In crack-sensitive metal*
- Insufficient electrode force
- Electrode too flat
- Insufficient "on" time
- Excessive current
- Insufficient "off" time
- Excessive roll speed

Excessive Indentation
- Electrode too sharp
- Insufficient electrode width
- Excessive electrode force
- Excessive current
- Excessive "on" time
- Insufficient coolant on electrodes

Unequal Penetration
- Unequal electrode dressing
- Unequal electrical or thermal conductivity of electrodes
- Unequal distribution of coolant on electrodes

Lack of Penetration in Both Sheets
- Electrode too flat
- Excessive electrode force
- Insufficient current
- Insufficient "on" time

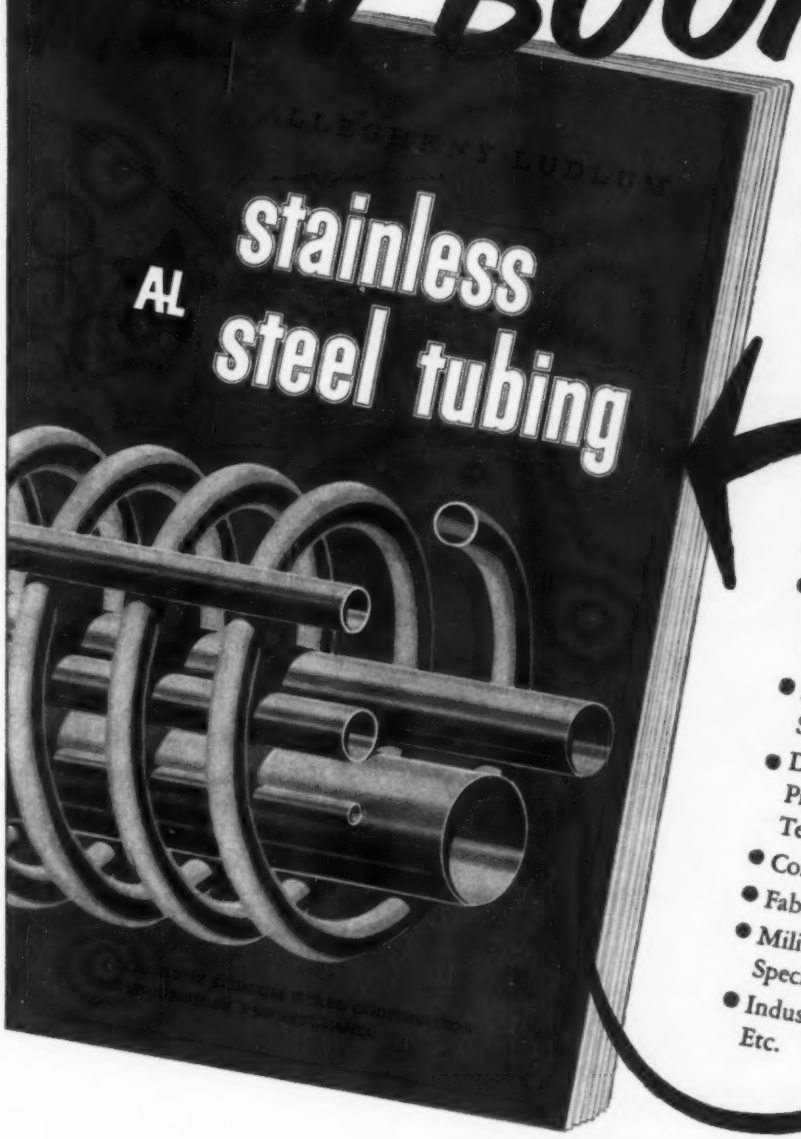
Lack of Penetration in Thinnest Sheet
- Electrode too flat
- Excessive electrode force
- Excessive electrical or thermal conductivity of electrode on thin sheet
- Insufficient electrical or thermal conductivity of electrode on heavy sheet

Excessive Penetration
- Excessive current or "on" time
- Electrode too sharp
- Insufficient coolant on electrodes
- Insufficient electrical or thermal conductivity of electrodes
- Insufficient electrode force

Scuffing
- Electrodes too hot
- Excessive current
- Insufficient electrode force
- Insufficient electrical or thermal conductivity of electrodes
- Electrode too sharp
- Rolls not synchronized (both rolls are driven)

**Courtesy Allegheny-Ludlum Steel Corp., Pittsburgh.*

NEW BOOKLET on STAINLESS STEEL TUBING sent on request



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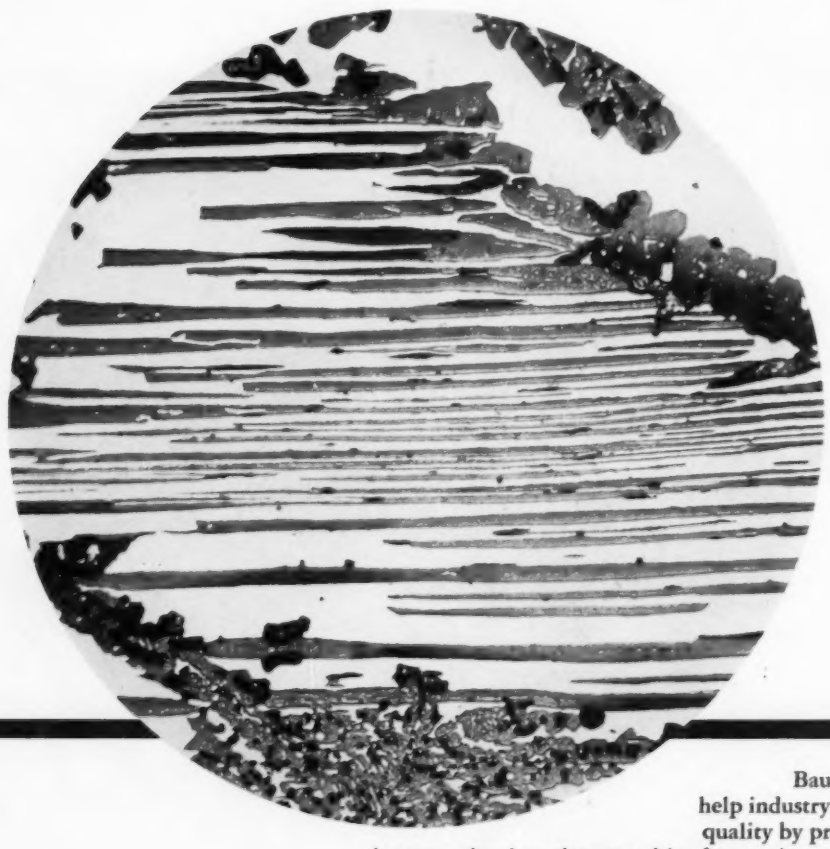

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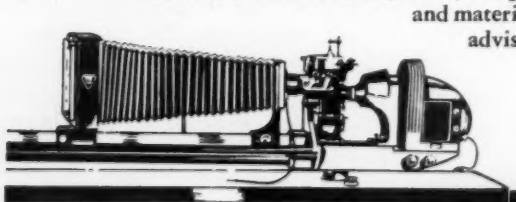

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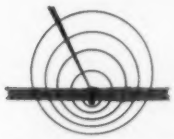


Frontiers of Welding Progress

Problems in Field Welding Chromium-Molybdenum Pipe

*By R. L. SKAGGS**

When welding these air hardening steels in the field, proper preheating and postheating, particularly the latter, are very important. Torches or ring burners are generally used. Among other items, this article also describes the use of preformed thermite assemblies for stress-relieving these welds in the field. (K9p, K9q, J1a; ST, 4-60)

CHROMIUM-MOLYBDENUM ALLOYS are used extensively in refinery piping which needs both strength and corrosion resistance at elevated temperature. However, the use of these alloys (which may contain up to 9% Cr and 1% Mo) has been restricted somewhat by difficulties in fabrication and repair caused by their air hardening characteristics. Unless proper preheat and postheat are applied, weld deposit and heat-affected zones may crack before final heat treatment. Thus, safe pre and postheating techniques must be established if such piping is to be used.

Before considering the effect of various heat treatments, it is important to understand the transformation characteristics of these alloys. Figure 1 shows the effect of composition upon critical temperatures. As can be seen, both the Ar_1 and Ar_3 are lowered by additions of chromium up to 3%, and thereafter they remain constant. The M_s and M_f temperatures, of interest because the bainitic reaction is suppressed above 3% Cr, are both depressed slightly by additional chromium. Throughout the composition range covered by the family of alloys, the "nose" of the TTT-curve remains between 1325 and 1375° F.

Hardening characteristics are summarized in Fig. 2. Of the alloys regularly used, the 5% Cr, 0.50% Mo composition displays the strongest tendency toward hardening. (The 9% Cr, 1% Mo and 7% Cr, 1% Mo compositions are rarely employed.) Since the 5% Cr, 0.50% Mo composition is most troublesome from a welding standpoint, this alloy was chosen for study. The findings can be applied, with some modification, to all other compositions in the group.

According to previous work, a preheat and interpass temperature of 500° F. will prevent cracking during welding.† Since this temperature can be achieved in the field with a fair degree of ease (with either torches or ring burners), preheating was not studied. However, postheating was another matter. Performed after welding and prior to final heat treatment, this treatment must provide a temporary structure tough enough to resist cracking from line reaction stresses, handling, thermal stresses, and the like. As performed today, postheating practice varies from immediate stress-relief after welding to slow cooling from preheat temperature. Immediate stress-relief is not always practical in the field, or even in the shop. On the other hand, if the part is cooled slowly after welding, the danger of cracking due to thermal stresses is eliminated, but the brittle as-welded structures in the weld

*Materials Engineer, Standard Oil Co., Richmond, Calif.

†"Welding of Medium Alloy Chrome-Moly Steels", by Kenneth R. Notvest, *Welding Journal Supplement*, Vol. 38, May 1959, p. 222-s-227-s.

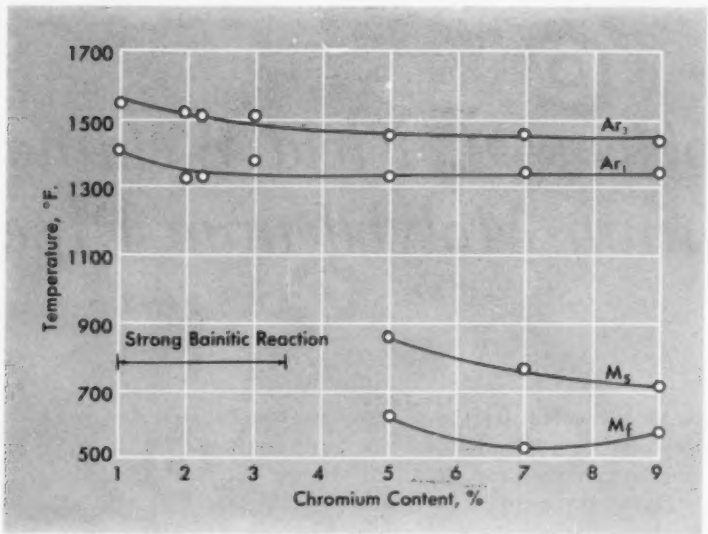


Fig. 1 — Variation of Critical Cooling Temperatures in Chromium-Molybdenum Alloys. The bainitic reaction is suppressed when chromium is above 3%

deposit and heat-affected zone are not altered. Some procedure which lies between these two extremes is needed to assure a safe interim structure.

Experimental Work

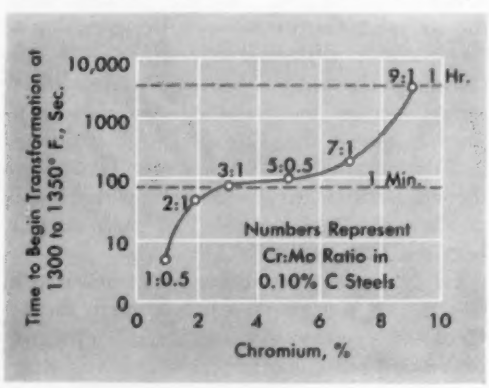
To determine the correct postheat practice, we evaluated three factors. These were relief of welding stresses, reduction of weld deposit hardness, and increase in weld metal and heat-affected zone toughness. Tests were made by placing a weld bead around one third of the circumference of a short length of 5% Cr, 0.50% Mo pipe. These specimens were then placed in furnaces at various temperatures and allowed to come to temperature before being removed to be cooled in air or under insulation. (Of course, furnace postheat is impossible in the field; we did it experimentally to insure uniform temperature.) As with preheating, field postheating is done with torches or ring burners.

To test these experimental postheat treatments, each weld was saw-cut at the midpoint and the gap measured with feeler gages. The amount of elastic springing was taken as a measure of residual stress after post treatment. As might be anticipated, residual stress decreased with postheating temperature to 1450° F., where the elastic spring fell to zero. This does not mean, however, that all stresses were removed. Stress level after heat treatment is a function of short-time yield strength at temperature, and the yield strength of the 5% Cr, 0.50% Mo alloy at 1450° F. is 5000 psi. The weld deposit softens but slightly at postheat temperatures below 1200° F.

A modified impact test bar, shown in Fig. 3 along with test results, was used to measure toughness. This design was chosen because it included the weld deposit and heat-affected zones in the material backing the notch. As can be seen, impact resistance is markedly improved with increased postheat temperature if air cooling is allowed.

On the basis of the three criteria studied,

Fig. 2 — Effect of Alloy Content on Hardenability of Chromium-Molybdenum Steels. Because the 5% Cr, 0.50% Mo alloy was the most troublesome (of the alloys regularly used) from a welding standpoint, it was chosen for study



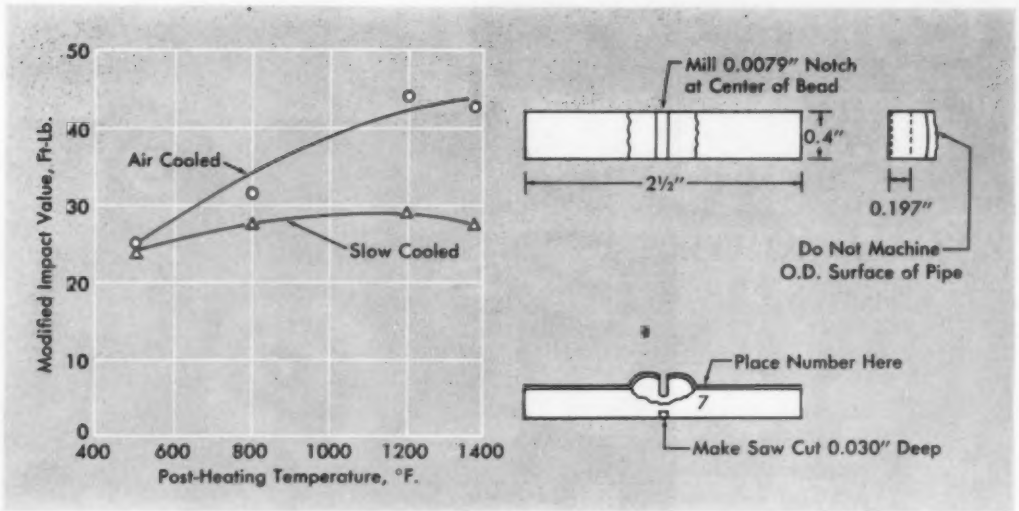


Fig. 3 – Effect of Postheat Temperature on Toughness of Weld Deposit as Measured by the Special Impact Test Which Is Also Illustrated. Note that air cooling insures a tougher structure

postheating between 1200 and 1375° F., followed by cooling in air, provides the best interim structure obtainable. Higher temperature should be avoided because there is danger of exceeding the lower critical temperature. Though the postheat procedure described above is not practical for large structures, it is easily accomplished on welds* in piping.

Final Heat Treatment

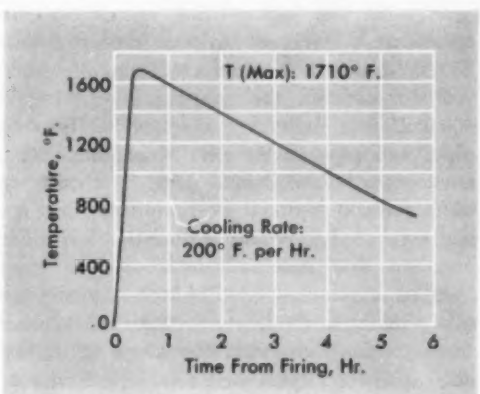
The welded and postheated pipe can be heat treated by stress-relieving or by a short-cycle anneal. Each of these methods, if properly applied, results in tough, ductile joints. To stress-relieve, heat 2 hr. at 1375° F. In the field, this is done with either induction or resistance heating.

Short-cycle annealing consists of heating above the lower critical temperature and cooling at a rate slow enough to prevent rehardening. Two systems are available. In the shop, welded parts can be furnace annealed, and in the field, exothermic assemblies which are commercially available† can be used. The tem-

*Electrode composition is very important. The manganese-to-silicon ratio greatly affects the ductility of stress-relieved chromium-molybdenum weld metal. Briefly, weld metal of good ductility can be obtained by adjusting this ratio upward with increases in carbon content. Analysis of several 5% Cr, 0.50% Mo test electrodes has shown that carbon, manganese, and silicon were carefully controlled by most of the electrode manufacturers. Carbon ranged from 0.05 to 0.08% while the manganese-to-silicon ratio was maintained between 0.5 and 1.5. Two other factors were also apparent. Up to about 0.07% carbon, the manganese-to-silicon ratio may be adjusted to obtain stress-relieved hardness in the range of Brinell 200, and by combining a high manganese-to-silicon ratio with low carbon, very low hardnesses are obtained. Maximum joint ductility is obtained by restricting the carbon content of the weld deposit. For 5% Cr, 0.50% Mo, a maximum of 0.06% was found sufficient. With alloys lower in chromium, somewhat higher carbon may be tolerated.

†Exo-Met Corp., Conneaut, Ohio.

Fig. 4 – Temperature Cycle for Exothermic Anneal. When the thermite is ignited, the temperature rises rapidly and drops slowly. The slow cooling rate prevents rehardening of the weld



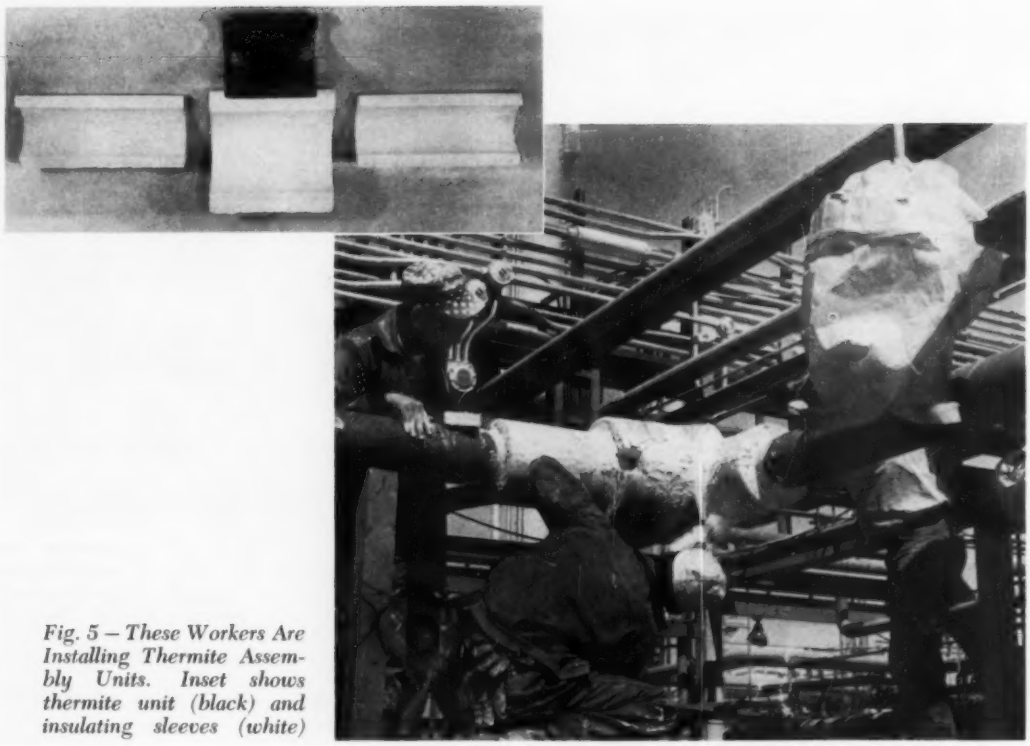


Fig. 5 – These Workers Are Installing Thermite Assembly Units. Inset shows thermite unit (black) and insulating sleeves (white)

perature cycle obtained in the field anneal is shown in Fig. 4. Components of one of these assemblies, a thermit heating mold and insulating sleeves to retard cooling, are shown in Fig. 5, along with a photo of the installation of the actual assembly.

The cooling rate necessary to prevent the weld deposit from rehardening is a function of carbon content. A microhardness survey of an annealed weld deposit showed a nearly constant hardness (about 170 DPH.) across the heat-affected zone, fusion line, and weld deposit. On the other hand, the stress-relief treatment left regions of local hardness up to 250 DPH. in the heat-affected zone.

Field trials of the process were made in April 1959. Eight low-alloy welds (pipe to pipe, and pipe to 90° ell) were annealed to hardnesses below Brinell 150. The cost was $270; for conventional stress-relieving the cost was estimated to be about double. The difference was due principally to labor costs.

Because a narrow band of high hardness usually remains in the heat-affected zone adjacent to the fusion line even after stress-relief, considerable ductility is desirable in the adjacent weld deposit. For this reason, the final hardness of the weld deposit is limited to Brinell 200 maximum.

Comparing the Two Methods

Both heat treatment methods are adequate from a technical standpoint and are permitted under the A.S.A. Pressure Piping Code, Petroleum Refinery Piping Section. However, the cost of the exothermic anneal treatment is roughly 50% that of conventional stress-relief where off-the-shelf thermite assemblies are used. For larger pipe sizes, it is necessary to use nonstandard fittings. Also, the higher alloys require special features to restrict cooling. These affects continue to lower the cost advantage.

There are other factors to consider, of course. While the uniform hardness across the weld provided by annealing is more desirable, electrical stress-relief is a more flexible method. It appears that the exothermic method will find its greatest application in new plant construction where a large number of welds are treated and where there is a favorable lead time to order such assemblies.

Frontiers of Welding Progress

Welding Solid-Fuel Rocket Motor Cases

*By P. J. RIEPPEL**

Hot cracking of weld metals and notch sensitivity of high-strength steels at maximum strength levels pose serious challenges to fabricators of rocket motor cases. Most failures stem from poor welding techniques and inadequate inspection. Some of the recommended practices to combat these problems are discussed. (K1, AY, SS, SGB-a)

WELDING OF THIN SECTIONS of high-strength steels in the fabrication of solid-fuel rocket motor cases represents a welding frontier very critical to our national defense. Although many fabricating methods have been and are being investigated, welding currently provides the most efficient means for the production of light, high-strength cases.

Success in this field requires extensive metallurgical knowledge, fabrication skills, and painstaking application of technical principles. Techniques used to produce carbon steel pressure vessels and some common low-alloy steel structures are not adequate for production of rocket motor cases.

A high percentage of the test failures of rocket components has originated in defects caused by inadequate welding techniques and quality control. In many instances, the defects were large enough to be observed easily during inspection. Welding is a highly satisfactory method of fabrication, but inadequate techniques and controls have led to many failures.

*Chief, Metals Joining Div., Battelle Memorial Institute, Columbus, Ohio. This paper is a summary of information from Defense Metals Information Center reports (DMIC Report No. 118, Oct. 12, 1959, and a recent DMIC memorandum) by M. D. Randall, R. E. Monroe, H. W. Mishler, and P. J. Rieppel. The information was collected with the cooperation of many companies in the aircraft and missile industries.

The purpose of this paper is to summarize information that deals exclusively with solid-fuel motor cases and to make recommendations for their welding. Steels, welding processes, welding conditions, filler metals, and inspection techniques are some of the major items that will be discussed.

Steels in Use

Four groups of high-strength steels are of current interest. These include low-alloy hardenable steels, hot work die steels, martensitic stainless steels, and precipitation hardenable stainless steels. The nominal compositions of these steels are shown in Table I.

Low-alloy hardenable steels have been employed extensively for motor cases. Many are modifications of A.I.S.I. 4340 and have been used by the aircraft industry for years. Some of the newer alloys such as 300 M and Airsteel X-200 have advantages over A.I.S.I. 4340. They have higher yield and tensile strengths (240,000 and 280,000 psi., respectively), they are air hardenable in light sections and they can be tempered at higher temperatures (about 600 to 700° F.) which may provide a small degree of stress-relief.

Experience in the Polaris program has shown that A.M.S. 6434 performs best when heat treated to about 185,000 psi. yield strength. Despite the impression created by initial diffi-

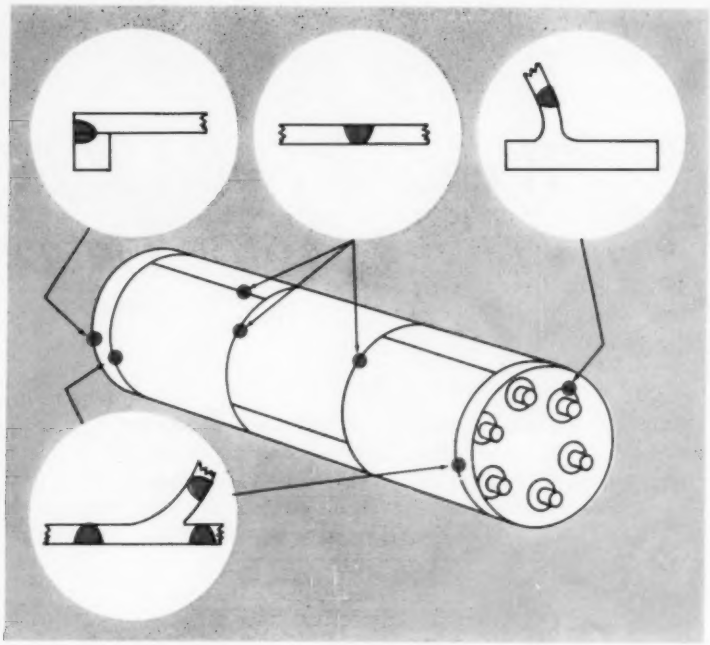


Fig. 1 – Various Weld Joints in Rocket Motor Cases

culties early in the program, low-alloy hardenable steels are quite weldable. Consumable and nonconsumable-electrode inert-gas-shielded welding and roll-spot resistance welding processes are the most satisfactory for this group of steels.

Hot work die steels are characterized by high hardenability, high strength (240,000 and 290,000 psi. yield strength and ultimate strength, respectively) and high-temperature tempering properties. They can be tempered at about 1000° F. Only a few of the alloys in this group have been used in the production of rockets. The inert-gas tungsten-arc and manual-coated electrode processes are satisfactory for these steels.

Martensitic stainless steels have the advantage of oxidation and corrosion resistance, but they have lower strengths (160,000 to 200,000 psi. yield) than the previous two groups. These steels are susceptible to cracking in the weld and heat-affected zone – an important consideration during their fabrication. Inert-gas-shielded tungsten-arc welding is recommended for the group.

Precipitation hardenable stainless steels are widely employed by the aircraft and missile industry but have found little use in solid-fuel rockets. Yield strength ranging from 160,000 to 185,000 psi. can be obtained with these steels. Cold work in thin strips increases the yield strength of AM 350 and AM 355 to 260,000 and 280,000 psi. AM 355 has been and is being used for spirally wrapped cases made from cold rolled stock 0.004 in. thick. These steels can be welded by several processes, but resistance spot welding is used to fabricate spirally wrapped cases.

Design for Welding

A great deal of effort has been spent to eliminate longitudinal weld seams on the assumption that this would produce better cases. The cylindrical sections for the Minuteman cases have been produced by hydrospinning, deep drawing, and machining from ring forgings. The components from these processes are joined to each other by a single butt-type girth joint at the center of the cylinder, or to heads at each end of the cylinder. Extra strength in the girth-weld areas has been provided by increasing shell thickness about 20% at the joint. The shell thickness is gradually tapered for 5 or 6 in. on each side of the joint if it is in the center of the cylinder. The value of completely removing weld reinforcements has been debated. Some believe that this operation does not provide worth-while improvement in stress distribution around the weld. In view of the small safety factor used in design, however, al-

Table I – Composition of Steels for Solid-Fuel Rocket Motor Cases

Steel Designation	Chemical Composition							
	C	Mn	Si	Cr	Ni	Mo	V	Other
				Low-Alloy Hardenable Steels				
17-22 AS	0.28-0.33	0.45-0.65	0.55-0.75	1.00-1.50	—	0.40-0.60	0.20-0.30	—
A.I.S.I. 4130	0.28-0.33	0.40-0.60	0.20-0.35	0.80-1.10	—	0.15-0.25	—	—
A.M.S. 6434	0.31-0.38	0.60-0.80	0.20-0.35	0.65-0.90	1.65-2.00	0.30-0.40	0.17-0.23	—
A.I.S.I. 4340	0.38-0.43	0.60-0.80	0.20-0.35	0.70-0.90	1.65-2.00	0.20-0.30	—	—
Airsteel X-200	0.41-0.46	0.75-1.00	1.40-1.75	1.90-2.25	—	0.45-0.60	0.03-0.08	—
300 M	0.41-0.46	0.65-0.90	1.45-1.80	0.70-0.95	1.65-2.00	0.30-0.45	0.05 min	—
MBMC-1	0.42-0.46	0.70-0.90	1.50-1.70	0.60-0.90	—	—	0.01 min	—
Ladish D-6	0.42-0.48	0.60-0.90	0.15-0.30	0.90-1.20	0.40-0.70	0.90-1.10	0.05-0.10	—
				Hot Work Die Steels				
Crucible 56	0.38-0.44	0.40-0.70	0.80-1.20	3.00-3.60	—	2.00-2.75	0.25-0.50	—
Crucible 218	0.40	0.40	1.05	5.00	—	1.35	0.50	—
Potomac A	0.40	0.30	0.90	5.00	—	1.30	0.50	—
Potomac M	0.40	0.30	1.00	5.00	—	1.00	1.00	—
Vascojet 1000	0.40	0.30	0.90	5.00	—	1.30	0.50	—
				Martensitic Stainless Steels				
Type 410	0.15 max	1.00 max	1.00 max	11.5-13.5	—	—	—	—
Type 419	0.25	—	—	12.0	0.5	0.5	0.25	3.0 W, 0.10 N
Type 422	0.23	0.75	0.35	12.0	0.8	1.0	0.25	1.0 W
12 MoV	0.25	0.50	0.50	12.0	0.5	1.0	0.3	—
Type 431	0.20 max	1.00 max	1.00 max	15.0-17.0	1.25-2.50	—	—	—
				Precipitation Hardenable Stainless Steels				
17-7 PH	0.09 max	1.00 max	1.00 max	16.0-18.0	6.50-7.75	—	—	0.75-1.50 Al
17-4 PH	0.04	0.60	0.40	17.0	4.0	—	—	4.0 Cu, 0.3 Cb+Ta
PH 15-7 Mo	0.09 max	1.00 max	1.00 max	14.0-16.0	6.50-7.75	2.0-3.0	—	0.75-1.50 Al
AM 350	0.12 max	0.90	0.50 max	16.0-17.0	4.0-5.0	2.5-3.25	—	0.07-0.13 N
AM 355	0.15 max	0.95	0.50 max	15.0-16.0	4.0-5.0	2.5-3.25	—	0.07-0.13 N

most any precaution that will minimize stress concentration is worth its cost.

Regardless of the pros and cons of these designs, most of the rocket cases have been fabricated by the roll and weld technique. A typical case configuration is shown in Fig. 1. Both longitudinal and girth welds are used. Some failures in longitudinal welds, encountered in the early period of rocket-case manufacture, have led many to believe that the design with longitudinal welds is poor. Actually, most, if not all, of the failures resulted from poor welding techniques and inadequate inspection, coupled with high notch sensitivity of steels. High notch sensitivity was usually associated with other than optimum heat treating practices.

Longitudinal welded seams have proved successful on Nike solid propellant cases. These 36-in. diameter cases are made from A.I.S.I. 4340 sheet 0.087 in. thick. The cylindrical parts of the cases contain two longitudinal welds because sheet was not available in proper width to make the cylinders from one piece. Cylindrical sections and the heads were heat treated to 208,000 psi. yield strength and then joined by resistance seam welding. Only one of 33 cases in one lot failed during hydrotest. This performance indicates that longitudinal welds can be satisfactory.

Weld-joint designs vary with thickness of steel. Square butt joints are used for thickness up to 0.10 in., single bevel with 90° included angle for 0.10 to 0.250-in. stock and double bevel for thicknesses over 0.250 in. The double bevel reduces distortion.

Welding Techniques

Associated with the welding operations are several factors such as filler-wire composition, fixturing, base-plate and filler-wire cleanliness, preheat, postheat, shielding gas, backup gas, heat input and stress-relieving over which good control must be maintained. The inert-gas-shielded consumable and nonconsumable electrode, the coated electrode and submerged-arc welding are the chief processes used for welding motor cases. As mentioned, resistance seam welding has been satisfactory in fabricating cases for the Nike. Spot welding has been used for welding spirally wrapped cases.

The first two methods have found greater application than the others. The inert-gas consumable-electrode welding was previously limited to material having a thickness greater than ⅛ in. New techniques or modifications of the method (Dip Transfer and short-arc processes) make it possible to weld very thin material successfully. Automatic welding with these methods, which is used almost exclusively in actual missile-case production, has a number of advantages over manual processes. It is easily used when preheat and postheat temperatures are 600° F. or higher. Uniform control of process variables such as current, arc voltage and travel speed is possible. Also, with automatic processes, welds are uniform in width, penetration and appearance. Some who prefer manual operation believe that the uniform weld-freezing pattern produced by automatic welding produces a weak zone along the center line of the weld where the columnar grains of the deposited weld meet. Data are not available to prove the superiority of welds produced by either process. In general, the benefits of automatic welding overshadow disadvantages.

Submerged-arc welding was used in the early periods of making large solid-fuel rocket cases. Problems with controlling weld composition and nonmetallic inclusions in joining thin-gage materials have reduced the use of this process, with preference for the gas-shielded processes.

Coated electrodes are available for welding many of the high-strength steels. Deposits made by these electrodes can be heat treated to the yield strengths of base materials. This type of welding is usually limited to short welds around fittings and similar applications.

Hot Cracking Reduced

The strength of welds and their tendency to crack depend greatly on filler-wire composition. A filler wire which matches the composition of the base metal is frequently used to insure the same heat treatment response by the weld and base plate. In some cases, there are advantages in having welds with lower strength than the base metal. For example, weld metals with yield strength below that of the base metal can be used in girth joints in the center of long thin-walled cylinders because the circumferential:longitudinal stress ratio is 2:1. Undermatching frequently permits use of ductile and tough weld metals. Longitudinal welds must match the steel strength because they are subjected to circumferential stress of the vessel.

The hot cracking susceptibility of welds is strongly dependent on the sulphur and phosphorus content of the wires and the base metal melted into the weld. Extensive research done at Battelle and verified by others shows that sulphur and phosphorus individually, or in combination, promote hot cracking. The sulphur and phosphorus of filler metals should not exceed 0.015% of either element or total more than 0.025%. Lower amounts are desirable. Many specifications for filler wire now require extra-low sulphur and phosphorus. Coated electrodes are available that will deposit welds with only small amounts of these two elements.

Good Fixtures Necessary

Money spent for adequate fixturing has proved to be a good investment. Several fabricators having small initial orders have attempted to "get by" with poor fixtures. Serious losses were sustained. Good fixturing is mandatory to align and hold the thin sheet for good weld control. Usually, it is desirable to fit fixtures with heaters to provide controlled preheat and postheat. The fixture also must provide means for manipulating the motor cases so that automatic girth and longitudinal welds can be made. In some instances, welds must be made on the inside as well as on the outside.

Porosity in welds is frequently caused by improper cleaning of base plate and filler wire. The surface of the base plate in the immediate vicinity of the weld should be thoroughly clean when welded. Filler wires are usually clean when received from the supplier; however, a constant check must be maintained to insure good results. Light copper coating on wire as received has no known effect on weld properties. The coating is only about 0.0002 in. thick.

Argon, helium and mixtures of the two gases are used for the gas-shielded processes. Helium is usually preferred because deeper penetration is obtained which permits the making of narrow single-pass welds. This is an advantage because narrow welds do not hot crack as often as wide welds. Two per cent oxygen in argon is usually not desirable due to oxidation of some alloying elements in the weld metals

Good jigs and fixtures usually are made to supply gas coverage to the back of the weld joint to prevent oxidation and obtain good bead contour. Argon is usually preferred for this purpose. Hot weld metal should not come in direct contact with copper backing bars because rapid chilling promotes cracking.

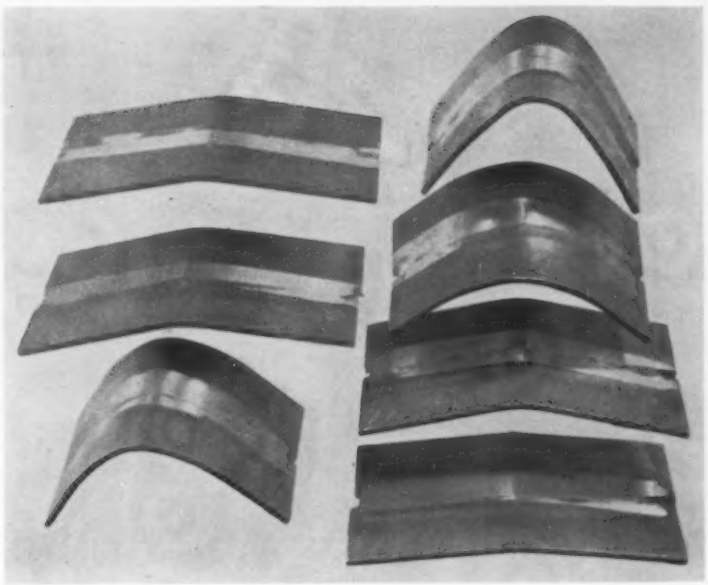


Fig. 2 – Effects of Postheat on Bend Ductility of 300 M Steel Welds. Postheat was held 30 min. for each

How Much Preheat and Postheat?

Preheat and postheat help to prevent weld-metal cracking and produce ductile as-deposited welds. As said previously, arrangements for proper temperature control can be provided as part of the fixtures.

The answer to the question "how much preheat and postheat?" is controversial. It depends upon the composition and metallurgical characteristics of the weld metal and base material. It is very important that the as-welded joints and base steel be reasonably ductile to prevent damage during handling which may include shipping prior to heat treatment.

Work done at Battelle has shown that the as-welded ductility of weldments in Airsteel X-200 and 300 M steels is determined by the preheat and postheat temperatures. This effect is illustrated by Fig. 2. The data were taken from welds made with the automatic inert-gas tungsten-arc process in a single pass. As-welded ductility of the specimens was directly related to the quantity of bainite in an otherwise martensitic microstructure. The relation between the quantity of bainite present and

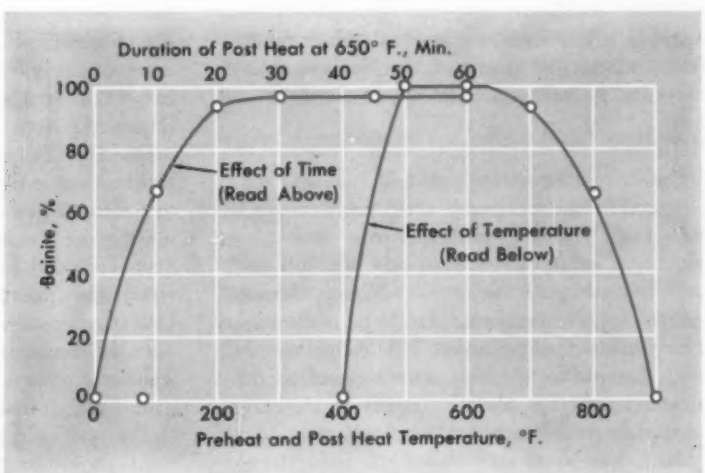


Fig. 3 – Effect of Postheat on 300 M Weld Microstructures. Presence of bainite in a martensitic microstructure increases the ductility of the weld

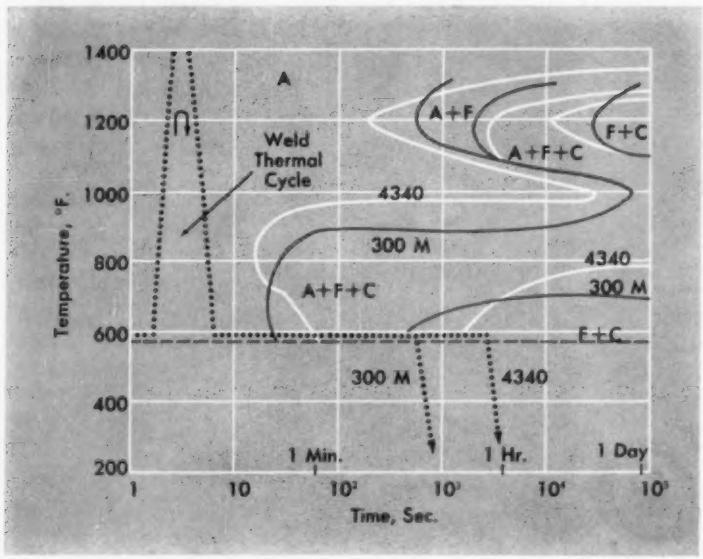


Fig. 4 – Typical Postweld Cycle Based on TTT–Curves for 300 M and A.I.S.I. 4340 Steels. Bainitic structure is desired for best weld ductility

the postheating temperature and postheating time is shown by Fig. 3.

The weld microstructure that can be expected to form on cooling can be approximated from the TTT-diagram for the particular steel. A TTT diagram for 300 M steel is shown in Fig. 4. The optimum preheating and postheating temperatures are in the range safely above the M_s temperature and considerably below the bainite bay temperature (flat portion of curve around 900° F.). At 650° F., only 30 min. is required to obtain a completely bainitic structure in this steel. The bainite bay of 300 M is typical of the low-alloy hardenable steels.

The TTT-diagrams for the hot work die steels are considerably different from those of the low-alloy hardenable steels. About 1000° F. postheat is required to obtain adequate ductility. Preheat and postheat temperature must, therefore, be tailored to fit the steel.

Keep Heat Input Low

The lowest heat input should be used that will produce an acceptable weld profile regardless of the welding process used. Excessive heat input enlarges the weld and heat-affected zone and increases incidence of hot cracking.

As a general rule, welds should be made with as few passes as possible. The welds should be as narrow as possible with respect to the thickness of the plate. Excessive welding usually tends to increase cracking.

Much has been said about when to stress-relieve the weld. Some say that stress-relief should be done before the weld is cooled from preheat or postheat. Others allow welds to cool to room temperature between welding and stress-relief. The action to take depends upon the steel. In general, the postweld treatment that produces a ductile microstructure is the one to use. Complete stress-relieving is not mandatory in most cases before the weldment is permitted to cool from postweld heating.

Experience has shown that many failures in steel rocket cases started at weld flaws that should have been detected. It is essential that adequate nondestructive inspection be provided to detect small flaws. Radiographic, magnetic-particle, dye-penetrant, and ultrasonic inspection have been successful. Usually, best results are obtained when two or more techniques are used to complement each other. Ultrasonic inspection is one of the most promising techniques for detecting small flaws.

Good procedures and techniques for repair welding are extremely important. A good rule to follow is to avoid repair welding until martensitic welds and heat-affected zones have been softened by tempering or annealing, or when the microstructure is ductile bainite. Localized preheating and postheating should be used during rewelding operations. Repair welds are always made under much higher restraint than initial welds. Thus, the possibilities of hot and cold cracking are greater. Repair welds should be inspected with extreme care.

Frontiers of Welding Progress

Instrumentation for Better Welds

*By D. J. LOGAN and W. K. MOEN**

Use of a multichannel recorder to chart the various functions in a mechanized fusion operation results in better weld quality, equipment maintenance and precise quality control. Upper control and lower control limits have been established for in-process control of each recorded parameter involved for each weld joint schedule. (S18, W29C)

MECHANIZED welding processes are used extensively in the fabrication of missile fuel tanks, equipment shells and many other components. Because of the complex parameters involved in inert-gas metal-arc welding, for example, it is imperative that a quality control program be maintained for periodic calibration and qualification of the welding equipment functions and control devices. Without such controls, it is difficult to pinpoint sources of weld defects.

Consider a recent investigation which was conducted at our Missile Division laboratory. We encountered difficulty with erratic penetration in producing a girth weld joining a 2014-T 6 forging ring to a 2024-T 3 aluminum shell. Determining which of the welding process functions was responsible for the unacceptable weld deposit proved impossible by visual inspection alone.

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Eight Functions Recorded

In the face of this situation, we decided to design and install pickup devices which would permit us to record the precise correlative parameters of the welding functions. Using a multichannel Sanborn Operations Recorder, it is possible to record simultaneously (Fig. 1) line voltage to the welding machine, arc voltage, welding current, weld travel speed, filler wire feed, shielding gas flow, weld bead height, weld time, malfunction location signals, and temperature of the electrode coolant. Mal-

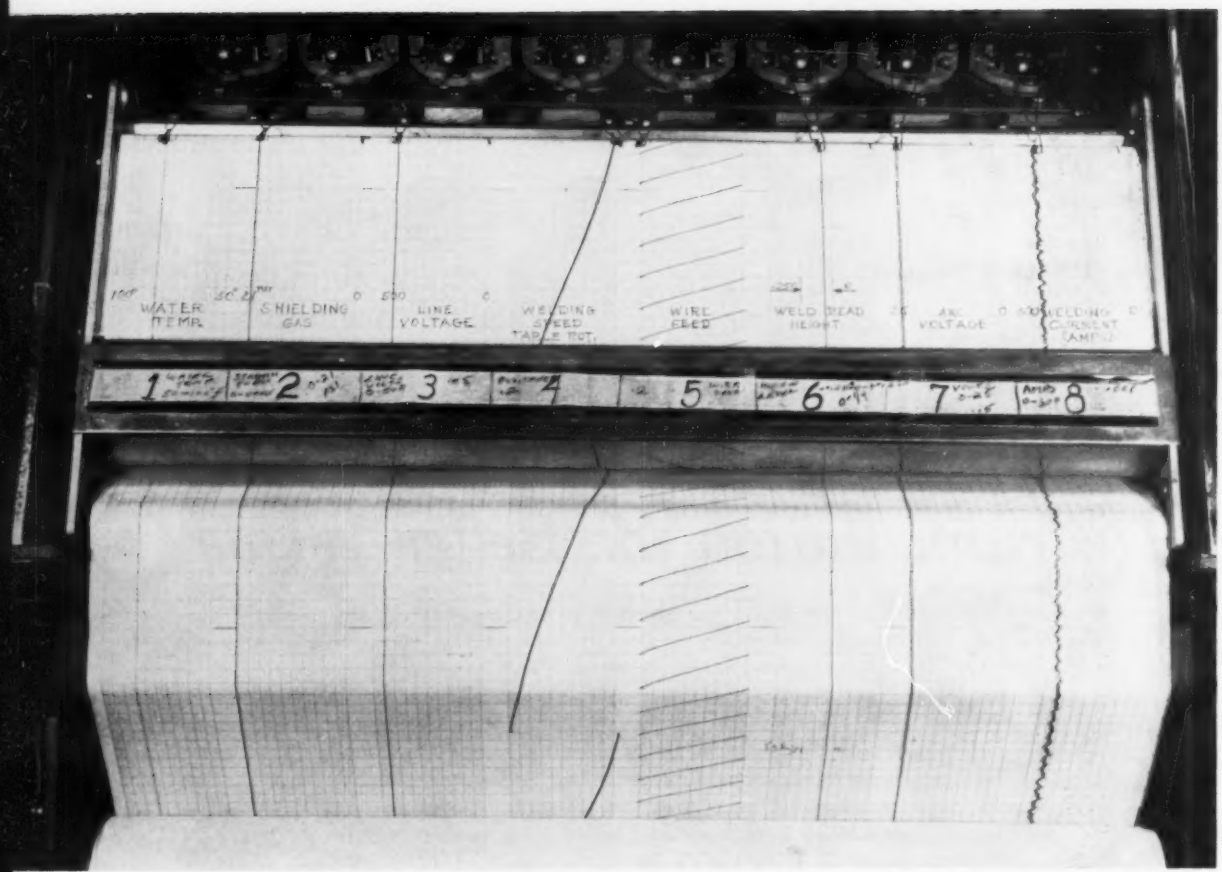

Fig. 1 – With Simultaneous Multichannel Recording of Eight Variables During Mechanized Welding, Operator Can Make Immediate Adjustments to Equipment Controls. Permanent record also helps pinpoint cause of weld defects

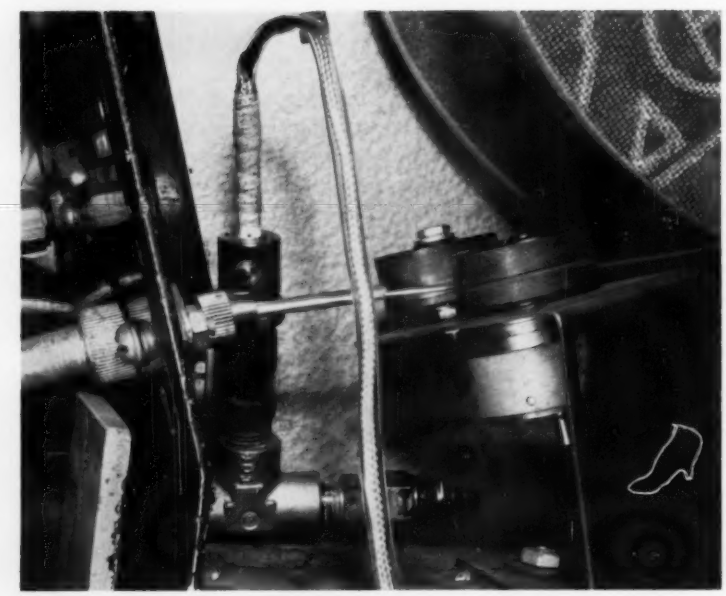

Fig. 2 – Rotary Potentiometer Pickup Is Used to Obtain Wire Feed and Deposition Rate

functioning of any one of these factors could result in a defective weld.

There are a number of advantages to the instrumentation system and the records which it supplies. For example, our maintenance department can use the recordings for trouble-shooting and for calibrating meters and control devices on mechanized welding equipment. A multiple recording made during operation of the equipment within specification requirements can serve as a basis for qualification of individual equipment installations. The recording of each parameter, as related to its respective upper and lower control limits, can be monitored during the welding operation. Thus, it is possible for the operator to adjust or correct any of the functional parameters while the weld is being made. Considered with radiographs of an individual weldment, recordings are helpful in analyzing the causes of rejected welds and premature weld failures.

Pickup Methods

As previously mentioned, all necessary information is fed to the recorder and charted simultaneously. The pickup devices consist of commercially available full Wheatstone bridge and precision potentiometer types. In the bridge-type, the excitation voltage is supplied to the transducer by the Sanborn Carrier preamplifier. The transducer returns a signal voltage to the carrier preamplifier which in turn, through the automatic recorder, produces a recording of the physical variable. Voltage was supplied to the precision potentiometer type of pickup by a d-c. battery. Physical variations cause a change in the resistance, which changes the signal voltage that is fed to the input of a Sanborn a-c., d-c. preamplifier and recorded directly proportional to the physical variable.

Line voltage at the welding machine is recorded on one of the eight channels to establish that the power supplied to the machine during the welding operation is constant without significant fluctuations. Arc voltage and current are also recorded simultaneously on separate channels to give a precise history of their normal minimum, maximum and average values, and to show abnormal fluctuations that may occur during the welding operation. To determine weld travel direction and speed, a rotary-type Helipot potentiometer, equipped with a roller, is attached to the weld positioner turntable. This supplies data on the uniformity or fluctuation of the turntable movement during the welding operation.

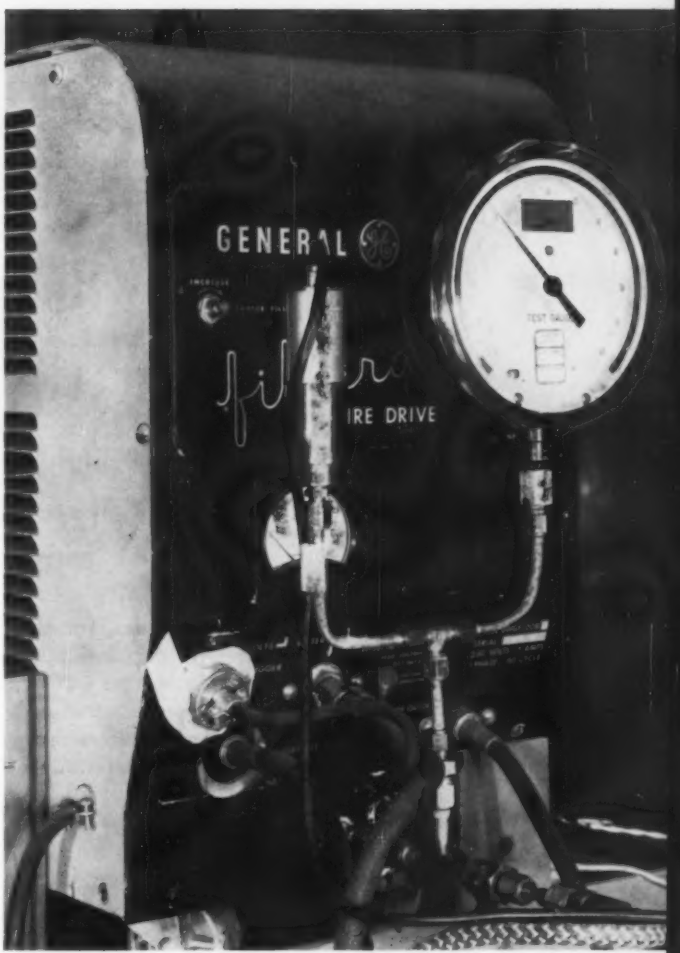

Fig. 3 – Rate of Flow of the Shielding Gas Is Sensed by a Transducer and Calibrated Orifice Arrangement. Transducer is shown on leg of T-joint opposite the pressure gage

Another Helipot potentiometer, with rollers, is attached to the weld filler wire (Fig. 2). When fed to the multichannel recorder, the information from this device indicates the uniformity of the feeding rate of the filler wire. It also measures the amount of wire deposited. A Statham pressure transducer, used with a previously calibrated orifice within the shielding gas line, records the amount and uniformity of flow of the inert gas. This arrangement, shown in Fig. 3, includes a line which leads from the main gas flow to a T-connection which

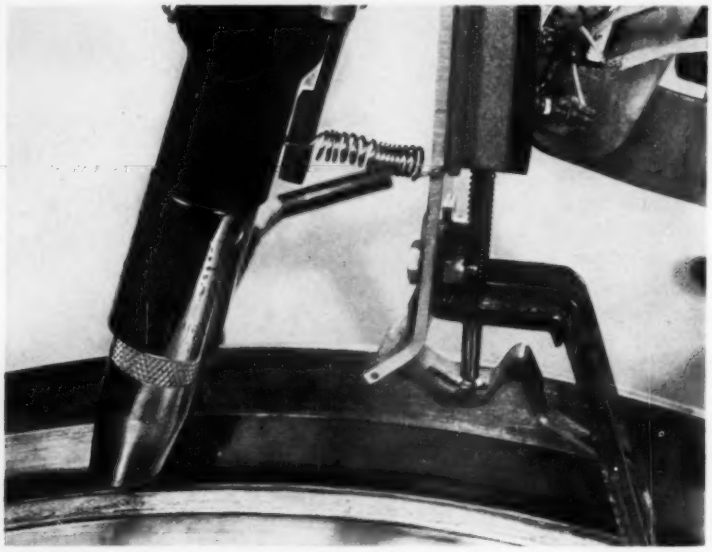

Fig. 4 — Device Shown Here, Essentially a Linear Potentiometer Actuated by an Arm, Measures the Height of the Weld Bead in Comparison With the Base Metal

branches off to the transducer and a pressure gage. To reveal excessive heating within the electrode head, we installed an Arthur C. Ruge resistance temperature transducer on the coolant outlet line. A Bourns linear potentiometer is employed to ascertain the weld deposit level in relation to the surface of the adjacent base metal. This also indicates the approximate amount (either sufficient, insufficient or excessive) of weld underbead accumulating during the single-pass welding operation. As shown in Fig. 4, the potentiometer is actuated by an arm which rides on top of the weld bead. Changes in resistance which indicate variation in weld bead height with relation to the base metal are recorded. Finally, for postweld studies of parameter variations that were observed during the welding operation, we included in the instrumentation a remote control microswitch. This is used by the operator to record a location signal on the chart and a corresponding spot on the weld.

Sources of Trouble Revealed

The usefulness of this control system is brought out by some of the discrepancies which it pinpointed during a welding run at our laboratory. In making a deposit by inert-gas metal-arc welding, the system showed that the actual welding current was 255 amp. although the current control was set at 280 amp. It also revealed erratic movement of the rotating work positioner and thus accounted for nonuniform joint penetration. Tungsten inclusions in the joint could be correlated with malfunctioning of the high-frequency arc-starting system which caused the tungsten electrode to dive into the weld. Areas of potentially poor mechanical properties in the weld area could be pinpointed by the chart where it revealed that the operator had reversed the direction of weld travel. The recording also showed that a concave weld was being deposited, thus permitting immediate correction.

In the light of our experience, our quality control department uses the instrumentation system to calibrate and check all meters and control devices on mechanized fusion welding equipment. This is done at least once every 30 days, whenever the equipment is relocated, and when maintenance may have affected previous calibrations.

The welding equipment is considered acceptable and qualified for production welding if test welds meet specified quality requirements and if a simultaneous recording reveals that all the equipment components are functioning within certain tolerances. For example, ammeters must maintain accuracy within $\pm 2\%$ of full-scale deflection. Voltmeter and arc voltage controls must maintain accuracy within ½ v., and the control mechanism for torch travel speed, positioner speed, filler wire feed, and gas flow meters must remain accurate within $\pm 5\%$ of the actual value of the respective meters used to adjust machine settings.

Dip Transfer Process: Low-Spatter Welding in Any Position

*By A. LESNEWICH**

DIP TRANSFER WELDING DIFFERS from the gas-shielded consumable-electrode welding (MIG) process in that the weld metal is transferred only by direct contact of the electrode and weld pool and not by the movement of molten droplets of metal through the arc. In general, Dip Transfer is achieved by modifying the characteristics of the power supply to obtain a low open-circuit voltage and proper electrical reactance and by using either a mixture of carbon dioxide and argon or pure carbon dioxide for shielding the arc.

Efficient Welding – Because the electrode is fed continuously at a controlled rate, very little, if any, manipulation of the arc is needed. The operator can work efficiently since essentially no spatter or slag are formed. In many production applications, the duty cycles approach and sometimes exceed 90%. This rate is impossible with covered electrodes since they require frequent change as consumed, frequent restrike of the arc, and cleaning of the deposit. The electrode diameter is kept under 1/16 in. and the current under 150 amp. for most applications, particularly those requiring little penetration or a small weld. By control of open-circuit voltage, electrical reactance, shielding-gas composition, and electrode diameter, contacts between the electrode and weld pool can be made to occur regularly and at a rate greater than 100 times per sec. With this operating condition, metal loss due to weld spatter decreases to less than 5%, and with very little skill, sound welds in poorly fitted joints of very thin or very heavy sections can be made in all positions. The wire feed (electrode melting rate) can be varied over a relatively wide range without readjustment of the generator settings.

The conventional MIG process, which uses relatively higher currents than the Dip Transfer method, is applied for the most part to the welding of flat – or horizontal – positioned joints between components having thicknesses greater than ⅛ in. The MIG process also is useful for joining aluminum in the vertical and overhead position. With steels, however, the fluidity of the weld metal and the absence of any flux for its support makes it difficult to weld joints that are positioned vertically. Without resorting to mechanized welding, thin sections cannot be joined in any position because of the penetrating character of the arc.

Thin Sections – The Dip Transfer process was conceived initially for all-position welding of thin metals using manual apparatus. Although it is applicable generally for all metals and with all shielding gases, its greatest potental when first introduced was considered to be the welding of mild steel in a carbon-dioxide shield. Most applications fall into this category. However, as the process matures, its uses in welding are increasing. The method is outstanding for joining thin sections with manual

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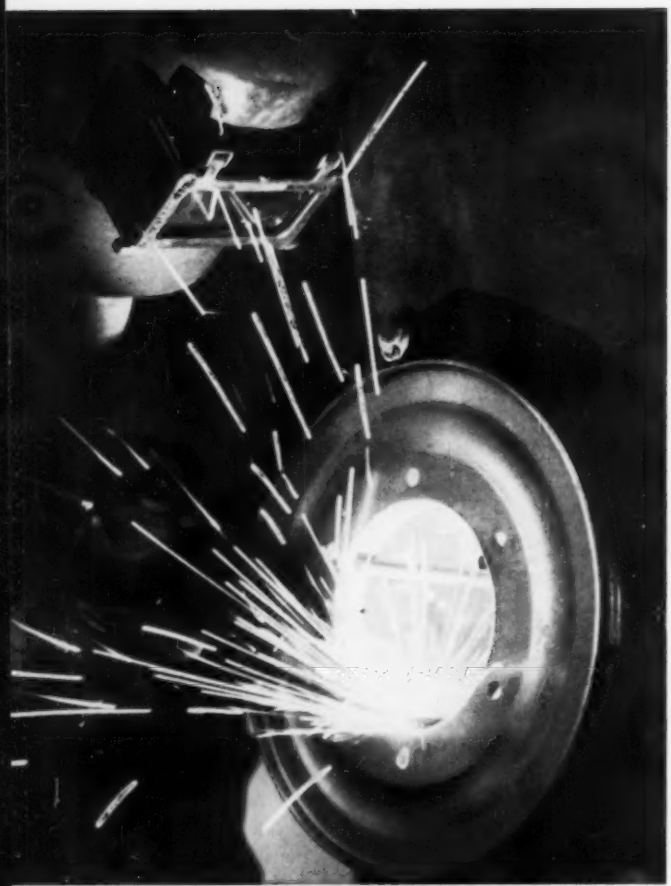

Fig. 1 – Dip Transfer Process Is Employed in Fabrication of Heavy-Duty Air Filters at Pur-O-Lator Products Inc., Wayne, Mich. Shown here is a tripod bracket, made of ⅜-in. mild steel, being welded to 0.030-in. walls of the filter housing

techniques. Welding steel sheet of 16 gage or thinner is very common. In one production application, the process welds ⅜-in. rod to 0.030-in. sheet steel. This is shown in Fig. 1. The same production item, a heavy-duty air filter, also contains Dip Transfer welds between 1-in. and ¼-in. plate, and ¼-in. and ⅛-in. steel.

One railroad company is using this approach to join 12-gage copper-bearing steel sheet for side panels for box cars. These are fastened to stiffeners and the frame in the vertical position with manual Dip Transfer apparatus.

Inasmuch as welding is possible in all positions and for extended periods with Dip Transfer, the method also is valuable for welding heavy sections that cannot be positioned. In the vertical position, deposition and electrode melting rate are greater than those possible with covered electrodes because slag does not have to be melted. At the same time, the complete absence of arc interruption permits the operator to weld at his convenience, rather than on a schedule determined by the fixed length of the covered electrode.

Cost Reductions – Because of these factors, considerable cost reductions are possible. One application being considered for Dip Transfer welding is large-diameter pipe of half-inch thickness which had been welded with E-6010 electrodes. Over 5 hr. total time was required to fabricate each joint with the covered electrode. Of this time, only 3 hr. was used for actual welding; the remainder was required for cleaning and other operations. Using Dip Transfer, the over-all time was reduced to about 3 hr. with an arc time of only 2 hr.; no cleanup time was required. As a result of the saving in time, the cost of welding this joint is expected to be reduced from $60 to $35. In this instance, pure carbon dioxide and 0.035-in. diameter mild steel welding wire were used.

In welding heavy sections of high-strength steels, care must be exercised to achieve the best possible joint quality without losing critical elements from the weld joint by oxidation. In such applications, mixtures of argon and carbon dioxide (generally 80% argon and 20% carbon dioxide) are preferred. Argon alone would neither permit the proper arc action for Dip Transfer nor allow adequate penetration of the weld pool. Carbon dioxide alone would be highly oxidizing.

Weld Heat Treated Steel – The mixture of gases is particularly useful for the fabrication of quenched and tempered steels having yield strengths of 80,000 to 120,000 psi. with a consumable electrode of nickel-molybdenum-vanadium steel. Such applications frequently require a weld metal with a combination of high yield strength and great toughness. Using an electrode with a nominal composition of 0.1% C, 1.25% Mn, 0.5% Si, 1.5% Ni and 0.5% Mo and a gas shield of 80% argon and 20% carbon dioxide, multiple-pass welds which were deposited with Dip Transfer methods developed an ultimate tensile strength of 112,000 psi., yield strength of 107,000 psi., and elongation of 26 ft-lb. at −60° F. as determined with a Charpy V-notch test specimen. These properties are equivalent to those normally achieved with the conventional MIG welds made in the flat position with an argon shield.

Applications

Welding Aluminum, Copper and Stainless Steel With Ultrasonics

*By J. BYRON JONES**

THOUGH LITTLE MORE THAN a laboratory curiosity a few years ago, ultrasonic welding has rapidly become a recognized production technique. As of today, this method has answered many welding problems. It is particularly useful for joining materials of thin gage (both sheet and wire) and dissimilar metals.

However, much work was needed before engineers were ready to accept this new welding system. This article reports some of this research and discusses early experiments in which metals with differing physical properties were welded. First, we needed to determine the power† required to produce ultrasonic welds in various metals. In ultrasonic welding, some metals and alloys are more difficult to weld than others, and the difference is related to various properties of the materials being welded. We selected 1100-H 18 aluminum, Type 302 stainless steel, and commercially pure half-hard copper, experience having shown that these metals require a broad range of power.

The investigations were carried out with the small, altogether functional, precision welding array shown in Fig. 1, which incorporates a force-insensitive mount for the transducer-coupling system. The SWR sensing elements are attached to this array.

For the resulting data to be meaningful, each material and each gage must be welded under about the same conditions. In other words, conditions should roughly optimize the power-clamping force relationships associated with the production of good welds. To do this, the metal was clamped at a given force and welded with a fixed pulse time. Power was progressively lessened until the spot welds, when peeled, failed by separation in the joint rather than by tear-out of the weld nugget. This procedure was repeated at the same fixed weld time, but at other arbitrarily selected values of clamping force, until enough information was obtained.

The result was a curve of clamping force against power; it represented the threshold values for welding as defined by the nugget pullout peel test. (The general curve shape is the same for a broad range of materials and thicknesses, and there is always a clearly defined minimum in required electrical power.

Acoustic power measurements were then made only at the machine settings that approximated the minimum power value which produced a quality weld. While this power was being measured, the oscilloscope trace was photographed with a motion picture camera. The areas included in these traces on consecutive film frames were individually measured, converted to acoustic power, and the power values plotted as a function of time to form an irregular curve. To obtain the acoustic energy, the area under this curve was integrated. The result was a rough value for the energy which produced the weld; however, it also included the power which passed through and beyond the weld zone and was dissipated in the anvil and its supports.

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*President, Aero-projects, Inc., West Chester, Pa. Much of the work reported in this article was obtained from fundamental research in ultrasonic welding, under Navy Contract No. NOas 58-108-c, carried out for the Airborne Equipment Div., Bureau of Aeronautics.

†A method has been devised for measuring the vibratory power that traverses an acoustical coupler to be delivered to the weld zone. The standing elastic wave ratio can be determined in a coupling bar by attached microphone elements which actuate a cathode ray oscilloscope. The standing wave ratio (SWR) is a function of the horizontal and vertical deflections of the oscilloscope trace, and the power transmitted along the coupler is proportional to the elliptical area of the trace.

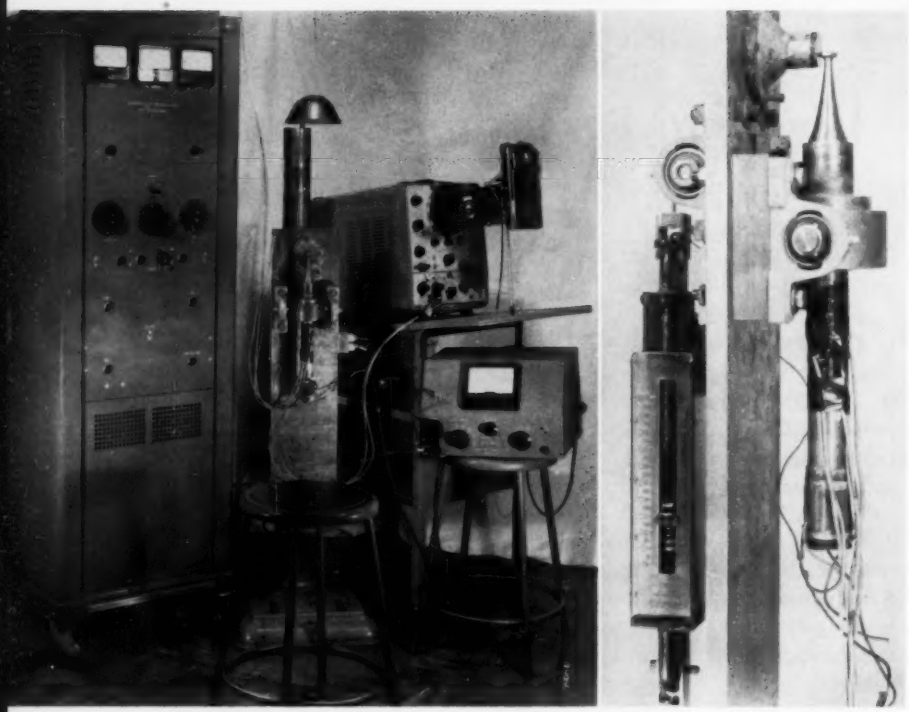


Fig. 1 – Small Precision Welding Array Used in Experiments. At the right is a closeup of the welding head which illustrates the standing wave ratio (SWR) sensing elements

There is a difference between electrical input power values and the acoustic power values; this represents the energy lost in transduction from electrical to acoustical energy. This energy loss is in very good agreement with the accepted values for efficiency of various transducer materials.

Weld Size – The foregoing relates to the acoustic power used to make a weld, but provides no data concerning the size of the weld. To eliminate this factor, we measured the areas of welds produced in each material and each thickness. The vibratory power used to make each weld was then divided by the weld area to give the required ultrasonic energy in watt-seconds per square millimeter of weld area. This was done for the three metals of interest, copper, aluminum, and stainless steel. Figure 2 illustrates the results.

Note that, at the thickness of 0.001 in., the power required to produce a weld of one unit area in the stainless steel is much larger than that required to produce a weld of the same

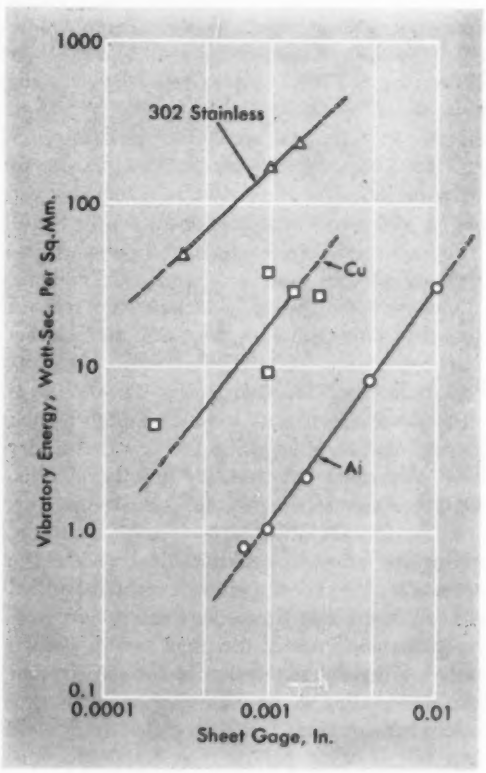


Fig. 2 – Minimum Vibratory Energy Needed to Produce Welds of 1 Sq.Mm. in the Three Metals

unit area in aluminum. Also, given identical thicknesses, the power required to produce a weld of the same area in copper is roughly ten times that required for aluminum. Though some metals require more power than the Type 302 stainless steel, the range between 1100 aluminum and Type 302 stainless seems to bracket the range of powers required for ultrasonic spot-type welds in many common materials.

An interesting point: Stainless steel requires more power than aluminum, and copper falls between the two. Quite a different situation prevails in the resistance welding of copper and aluminum because of the high thermal conductivity and low electrical resistivity of these two metals. Other factors to consider are the thermal diffusivity and the thickness of an acoustically absorbent plastic zone. Both should approach zero as the "zero thickness" condition is approached. The slopes of these curves will be of significance in connection with the fundamental mechanism of ultrasonic welding.

Though this work has been extended to substantially greater thicknesses and to many materials, we have presented the information for the thinner gages of these three metals because of the interesting ideas implied by the research. As an example, typical shear strengths for spot-type welds in the thicker gages of these metals are plotted in Fig. 3. Note that the curves for the three are in the same relative positions as the curves for the power requirements in Fig. 2. The vertical bars at each point represent 90% confidence intervals about the mean strength. Obviously, weld strengths are very consistent. For both aluminum and copper, the scatter on the 90% confidence level is within 20 lb. of the mean; for the stainless steel, the scatter is within 40 or 50 lb. of the mean.

Microstructures – Microscopic examination of ultrasonic welds revealed several features. For example, there was substantial internal deformation in aluminum welds; this is characteristic of vibratory welds in some materials. At the same time, the over-all thickness deformation was negligible – generally less than 5% of the total thickness. In some areas of the interface, the oxide film broke up and dispersed. As with aluminum, there was evidence of a high degree of working in the interfacial area of copper welds. The metal in this area may also recrystallize, and grains have been known to grow across the original interface. Strain hardening occurs in the stainless steel welds. Surface films have also been dispersed.

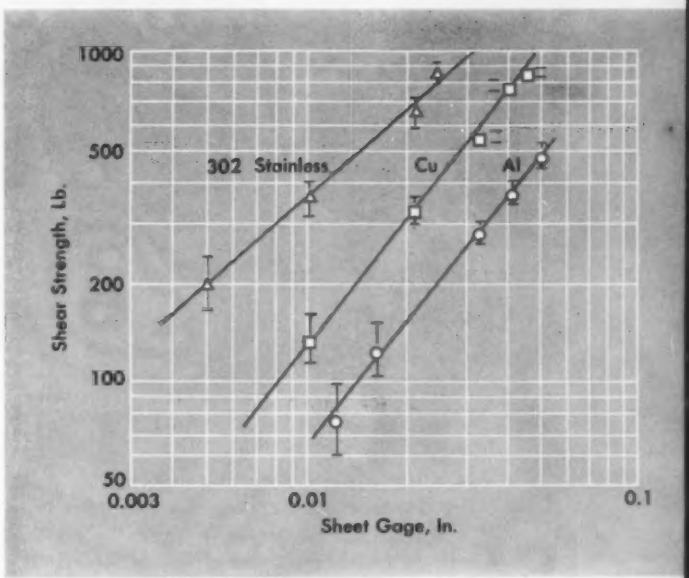


Fig. 3 – Strengths of Ultrasonic Welds. Vertical lines denote 90% confidence limits

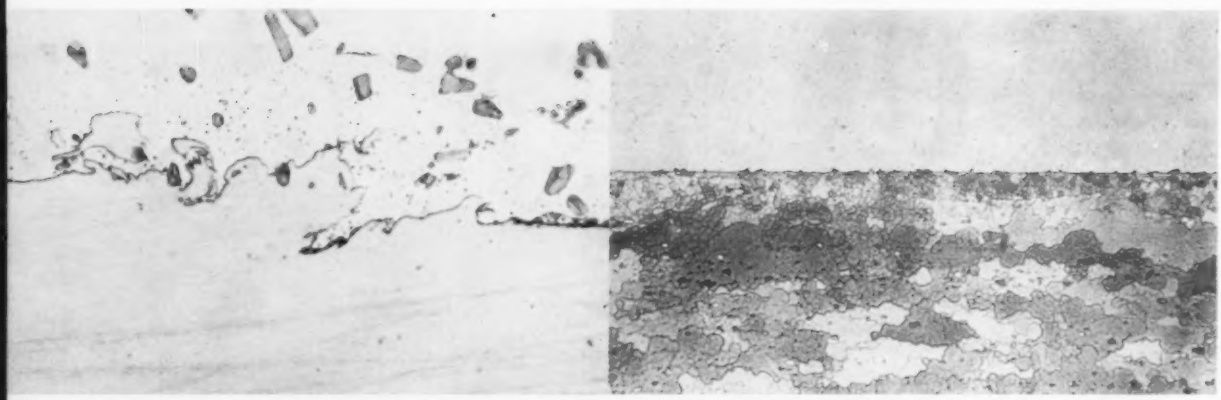
Bimetal ultrasonic welds of these three metals are interesting, both microscopically and from a strength viewpoint. Table I summarizes representative shear strength data for welds between various aluminum alloys and copper, aluminum alloys and stainless steel, and copper and stainless steel. The strength scatter with this group of welds is low, ranging from 10 to 40 lb. of the mean strength.

The metallographic characteristics of bimetal welds in these materials are illustrated in Fig. 4. The weld between aluminum and copper

Table I – Shear Strength of Bimetal Ultrasonic Welds

Material	Sheet Gage	Material	Sheet Gage	Shear Strength* of Spot
Aluminum 1100-H18	0.009 in. 0.061	Copper	0.010 in. 0.042	60 ± 10 lb. 850 ± 10
Aluminum 2014-T6	0.032 0.040	Copper	0.063 0.063	950 ± 40 1090 ± 40
Aluminum 6061-T6	0.020 0.030	Type 321 Stainless	0.012 0.030	300 ± 10 870 ± 30
Aluminum 2014-T6	0.032 0.040	Type 321 Stainless	0.012 0.012	300 ± 10 330 ± 10
Copper	0.063	Type 302 Stainless	0.020	570 ± 30

*Mean value with 90% confidence interval.



Al-Cu Weld; Etchant, 0.5% HF, 900 × *Al-Stainless Weld; Etchant, Electrolytic Oxalic, 300×*

Fig. 4 — Ultrasonic Welds in Two-Metal Combinations. At the left, the aluminum-copper bond displays much turbulence; this occurs because the two metals have similar properties. Where the properties are very different, this turbulence does not occur as is shown by the aluminum-stainless steel weld at right

shows the same interfacial deformation that characterizes some monometal welds. Because of the high turbulence that occurs when the weld is formed, bits of the copper have been torn off. They appear as islands in the aluminum matrix. Though interpenetration between the sheets is substantial, there is no evidence of alloying or diffusion such as usually occurs with fusion-type welds.

When the physical properties of the materials are far apart, as with the aluminum-steel and copper-steel welds, we do not encounter the high penetration that is evident with the copper-aluminum combination. The lessened heat sink and greatly differing thermal properties associated with the steel-aluminum combination are reflected in evidence of high temperature in the recrystallized aluminum structure near the interface.

In conclusion, it is apparent that ultrasonic welding will not only join materials embracing a broad range of properties, but will join such different metals as aluminum, copper, and stainless steel in bimetal combinations. Since this process is also effective in joining very thin foils and very fine wires, it is not surprising that it is receiving more and more acceptance in production applications.

Applications

High-Frequency Resistance Welding Fills Need for Fast Joining Method

*By WALLACE C. RUDD**

HIGH-FREQUENCY RESISTANCE WELDING is now an accepted high-speed method throughout the world for joining metals ranging from steel to copper to titanium in a variety of forms. It is based on relatively simple principles of electricity which have only been used commercially in the past nine years. High-frequency current at about 450,000 cycles per sec. is brought directly into the pieces to be welded through small sliding or rolling contacts. The current, which flows only to a depth of a few thousandths of an inch due to its high fre-

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quency, is led in the desired heating path by deliberately arranging the path so that it has minimum inductance. With low frequencies (60 cycles) the current always flows in the low resistance path, but at high frequencies it normally flows in the low resistance or low inductance path which may be considerably longer in length. The inductance or reactance of an electrical circuit can be adjusted so that the current flows where it is desired, whereas with low frequency the path is fixed since the resistance of the material cannot be adjusted.

At present, tube and pipe of steel and copper, in diameters from ⅜ to 16 in. and in wall thicknesses from 0.01 to 0.460 in., are being welded commercially by high-frequency techniques. Welding speeds range from 20 to 400 ft. per min. Containers made of conventional tin plate are also welded with a mashed lap weld, at speeds in excess of 1000 ft. per min. Sheathing is being applied to telephone and power cables by welding the sheath directly around the insulated cable and then corrugating it in the same operation to give flexibility.

New Fields – The newest use for high-frequency welding is in the manufacture of large-diameter pipe made from hot rolled, unpickled steel. Many installations are in operation for welding line pipe up to 16 in. in diameter with ⅜-in. or heavier wall. A recent installation welds pipe of 36 in. diameter and ½-in. wall thickness at a speed of about 50 ft. per min. using a 280-kw. welding unit. Several advantages of the welding process in this field are that the mill scale need not be removed and the quality of the steel, insofar as laminations and segregation are concerned, becomes relatively unimportant since the process welds laminated steel without difficulty.

The method is used also in the manufacture of spiral pipe 1½ to 96 in. in diameter. Strip is fed into a spiral forming mill in which the edges are abutted with previous turns or overlapped, depending on the type of weld desired. High-frequency power is brought into the weld area by contacts which touch both the entering strip and the following turn. In butt welding, the two edges are pressed together by a variety of schemes, and in lap or mashed lap welding an external squeeze roll presses the two pieces together in a forged weld.

Figure 1 shows a mill which forms and welds spiral tubing 2½ in. diameter and 0.015 in. in wall thickness at a rate of 150 or 300 ft. per min., depending on the size of welder. Such a mill would be suitable for making the stainless steel tubing for flexible metal hose.

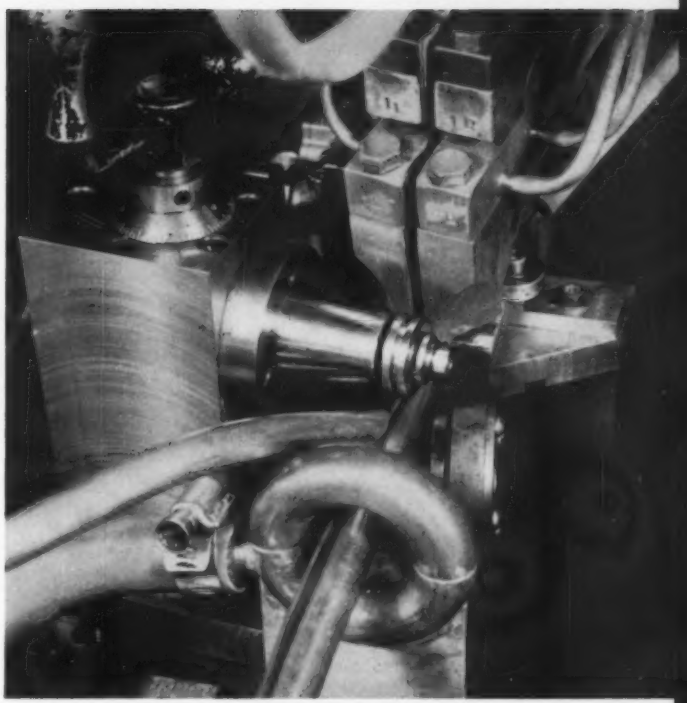

Fig. 1 – High-Speed Mill Forms and Welds Spiral Tubing. With high-frequency welding, tubing can be produced at the rate of 300 ft. per min.

An unusual application is welding a spiral fin to zirconium or steel tubing. A mill has been built for welding a spiral fin with a 10-in. pitch to a tube ⅝ in. in diameter at a rate in the range of 100 ft. per min. Zirconium tubing is welded by this mill for atomic reactors.

For heat exchangers, spiral fins 1 in. high and approximately ⅛ in. thick have been welded to 4-in. diameter tubing with a space between fins of some ⅜ in. The pitch can be varied widely as well as the height, thickness and shape of the fin.

The first unit of an entirely new high-frequency resistance welding process is now being installed for producing small-diameter steel tubing. This so-called "in-line" method involves flowing a single line of high-frequency current longitudinally in the seam being welded by placing two tandem contacts just before the squeeze rolls. With this new development, tubing of very small diameter and thin materials can be welded at high rates with an almost insignificant bead on the inside of the tube.

This is ideally suited for welding small tubing of stainless steel, Inconel, Incoloy, steel and copper and may be applicable to many other materials. One obvious field is in the fabrication of sheathing for resistance heaters.

Things to Come – In the rolling of structural shapes, the relative dimensions of such members as I-beams and Z-bars are often limited by available rolling techniques. Actually, greater stiffness, strength-carrying ability, and other desirable properties could be achieved if there were better distribution of metal in these members. One method of accomplishing this is to make them as weldments. I-beams, Z-bars, box beams and channels can easily be welded at very high rates from coil stock using high-frequency resistance techniques.

Many products such as large-diameter pipe require strip widths much wider than that produced in conventional rolling mills. This is particularly true in many foreign countries. High-frequency resistance welding can be used to weld continuously two coils of strip side by side in a butt weld. In this application, the upset produced in the weld is scarfed off on both sides and the double-width strip passes through a roller leveler and then into a double coiler producing a single coil of twice the width. This may also be of considerable interest to the auto industry for body work.

Applications

Percussion Welding Makes Quick, Low-Cost Wire Connections

*By J. S. GELLATLY, K. F. JOHNSON and A. L. QUINLAN**

ONE OF THE PROMISING NEW TECHNIQUES for metal joining, low-voltage percussion welding – a specialized form of arc welding – has reached a stage of reliability and quality which makes it attractive for selected applications. At Western Electric our work with percussion welding was motivated by the need for faster and cheaper ways of connecting wires to terminals. For this job, it is necessary that the joining method be adaptable to automatic production and that it produce a joint of low, constant electrical resistance. In addition, the connecting tool should be reliable and fast and should not cause heat damage to plastic-insulated wires.

Percussion welding offers great potential in meeting these requirements. In addition, it possesses a number of other desirable characteristics: it will weld refractory metals and those of high electrical conductivity. Heat-affected zones are practically nonexistent. The process also requires a minimum of energy. Of special importance, percussion welding can be accomplished in spaces impractical for soldering or wire wrapping, the standard techniques for connecting wires. No filler metal such as solder is needed.

In essence, percussion welding is a direct capacitor-discharge arc method in which weld energy is controlled by the capacitance included in the welding circuit, the voltage to which the capacitors are charged and the duration of the arc. The weld is formed with a bright flash and a sharp crack similar to the noise of a tiny firecracker. In welding by percussion, one of the parts to be joined is held firmly in such a position that the other part may be projected toward it at high velocity. The projected part must, of course, also be firmly held in proper alignment. The moving member is usually spring driven and separation of the parts to be joined is from 0.050 to 0.25 in. in the loaded and cocked position. A velocity of 80 to 150 in. per sec. is achieved prior to arc extinction.

*Mr. Gellatly and Mr. Quinlan are senior staff engineers and Mr. Johnson is department chief, Metal Joining Development, Hawthorne Works, Western Electric Co., Inc., Chicago.

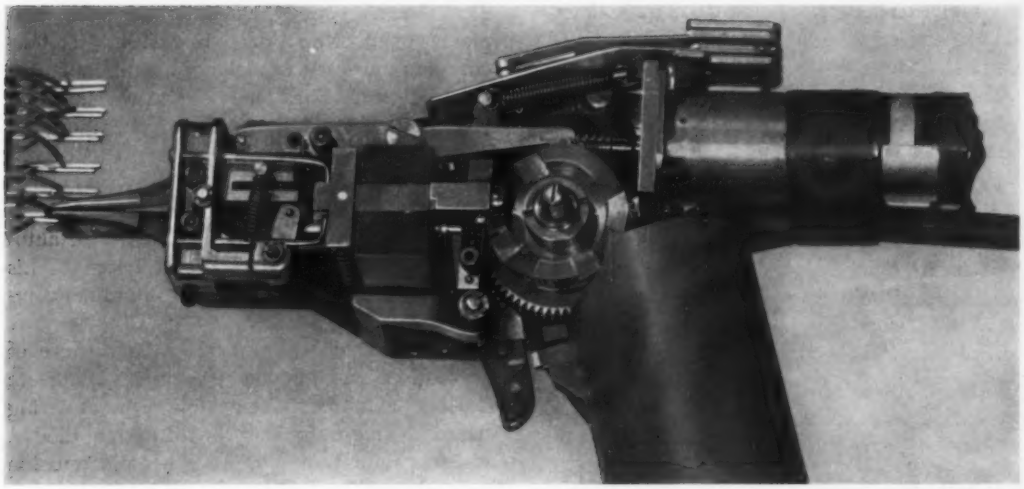

Fig. 1 – Motor-Driven Hand Gun Connects Wire to Terminal by Percussion Welding. Gun operates at 50 v., for personnel safety, and the 1500-microfarad capacitor is in the gun handle

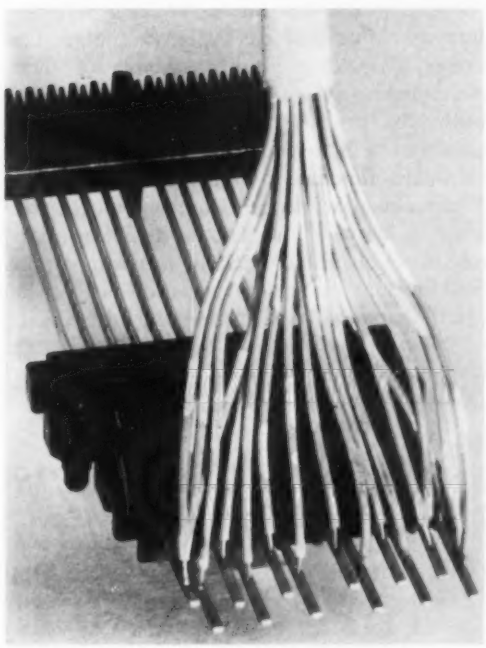

Fig. 2 – Typical Application of Percussion Welding Is to Join Connecting Wires to Terminal Ends of Wire Spring Relay Combs. Relay is about 1½ in. wide

The arc is started at about the point of contact of the two surfaces to be joined. Heat of the arc melts back the tip of the projected member at a faster rate than it is moving forward. The arc is thus able to spread over the whole mating area and melt a thin layer, perhaps 0.005 to 0.015 in. in both parts. It is extinguished after 150 to 600 microsec. by the physical contact of the molten surfaces. Momentum of the moving parts and remaining compression of the driving spring force the parts together.

Hand Gun – Work has been done on a hand gun for making wire to terminal connections by percussion welding. Figure 1 shows the current model. Typically, the gun may be used to weld connecting wires to the terminal ends of wire spring relay combs as shown in Fig. 2. The combs consist of a molded plastic block with wire "springs" which have precious metal contacts percussion welded opposite the terminal ends.

Welds made by this gun are of good quality with no voids or changes in microstructure beyond a narrow band a few mils deep. There is little reduction in hardness except in the immediate weld zone. In straight tensile tests most of the samples break in the wire, well away from the weld.

Applications in Electronics – Where can percussion welding be employed? Most of the work has been done on wire and terminal configurations and on rod and tape forms. Wire diameters from 0.006 to 0.102 in. have been welded. Studies indicate that copper and aluminum wire can be joined to a variety of metals by percussion welding.

One current application, for example, is in

attaching tinned copper leads, 0.012 in. in diameter, to the nickel-iron terminals of dry reed switches. This can be accomplished even with badly oxidized terminals and is an attractive prospect since it will replace a difficult hand wrapping and soldering method.

The fabrication of ground rods is another proposed application for percussion welding. Current practice is to connect a copper lead, 0.102 in. in diameter, to a steel ground rod by swaging and soldering. Attaching this relatively thick lead by percussion welding has proved practical.

Another application which has been investigated is the attaching of leads to deposited carbon resistors. The leads are presently connected to resistor caps by riveting. On resistors for use on defense projects, the joint must be soldered to insure a sound electrical connection. Studies have shown that tinned copper lead wires can be percussion welded to brass resistor caps to meet military specifications. A fully automatic cap-lead welder has been designed and put in operation for this purpose.

Automatic Equipment Designed—When considering the design of a new product percussion welding can best be used by adapting the design for the process.

An example of this approach to a new product is in the Automatic Number Identifier board. This is a network which determines the call-placing number on a party line circuit, for toll-charging purposes, in place of manual operator identification. Both leads of the resistors and capacitors are simultaneously welded on the network board which was designed to permit these components to be attached by percussion welding. The current product is being manufactured on the prototype design for an automatic welder now under construction. This new machine will weld 4800 two-terminal components per hr.

Another area of consideration is the use of percussion welding for mounting solid-state devices and components on printed-wiring boards. In a preliminary board design, diodes, resistors, and transistor have been percussion welded to 6.7-mil foil.

Studies made thus far in the area of component welding indicate many advantages for percussion welding in the assembly of electronic packages. The short weld cycle and the ability to handle components automatically contribute to high-speed assembly. Heat-sensitive solid-state devices can safely be connected by percussion welding. No temperature rise except at the weld zone can be detected in the welded wire. Elimination of soldering problems, such as surface preparation, flux, additional filler material and cleaning, lowers cost.

Applications

Two-Step Process Mates and Joins Parts in Pilot Projection Welding

*By D. C. WILLIAMS**

ENGINEERS ARE CONSTANTLY investigating every possible method of fastening parts of mechanisms together more economically and with higher quality – in line with modern technological advances.

In reviewing our fastening methods at Addressograph-Multigraph Corp. about ten years ago, we found a real need for methods other than copper brazing, riveting, staking and standard spot and projection resistance welding in fabricating assemblies of low-carbon steel. Resistance welding, in its many variations, offered the most possibilities for investigation. Since necessity is still the mother of invention, we developed a resistance welding method known as pilot projection welding.

Our primary aim was to produce reliably strong assemblies with accurately located component parts. Although we are equipped for copper brazing, riveting and staking, we chose to develop a new fastening technique because of shortcomings of these conventional meth-

*Chief Metallurgist, Addressograph-Multigraph Corp., Cleveland.

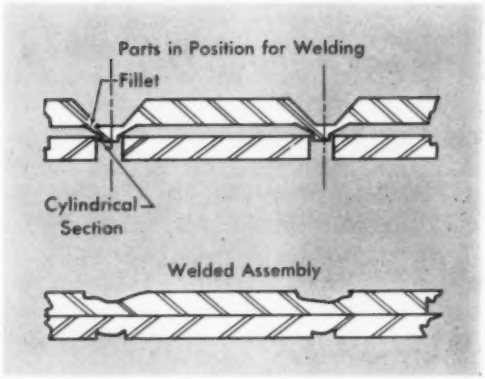

Fig. 1 – Cross Section of Components Before and After Pilot Projection Welding. Cylindrical section serves as a pilot or locator; fillet serves as projection which contacts corner of hole to permit current flow concentration

ods. In copper brazing, for example, the as-brazed component parts often require heat treatment to bring them back to usable hardness. With complex and accurately located parts, furnacing would be difficult due to the need for aligning and supporting fixtures.

Riveting is slow and quality is often dependent upon the operator. Frequently, only one rivet head can be made at a time. Heat treating of the assembly is not recommended.

Staking is a fast process but the possibility of the joint loosening is always present. Also, heat treating of a staked assembly is not recommended.

Advantages – The nature of resistance welding by projection offers the most advantages. Over-all dimensions are no problem. Usually no heat treatment is required to stiffen as-welded assemblies. When heat treatment is necessary, it can be done without affecting the weld joint. In addition, resistance welding by projection provides more trouble-free joints in meeting strength requirements. It can also be made a multi-point joining process.

For our purposes, projection welding has two distinct disadvantages. It requires welding fixtures which may be clumsy and heavy. Also, the method must allow for "travel" when the projection point compresses during the welding operation.

Pilot projection welding was developed to circumvent these shortcomings and, at the same time, to permit accurate location of welded components while meeting projection weld strength requirements set by A.W.S. Standards.

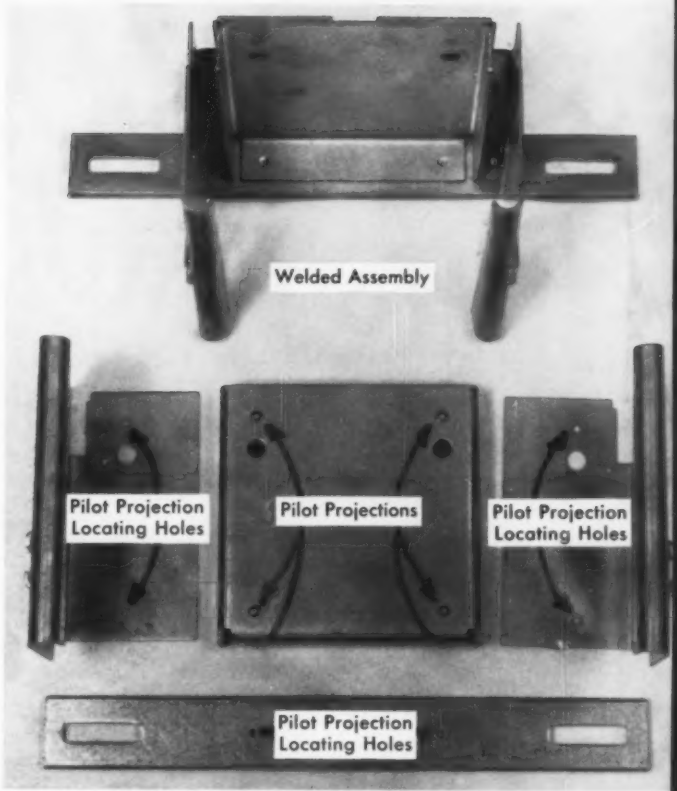

Fig. 2 – Typical Business Machine Part Assembled by Pilot Projection Welding. Method was developed for fabricating assemblies of low-carbon steel

Parts Mated – The projection developed was that of a truncated cone with a cylindrical section projecting from the truncate minor diameter section. The truncate cone section serves as the welding "projection" through which welding current is passed and is thereby concentrated. The cylindrical section serves as the "pilot" or locator. The pilot is mated with or is positioned into a drilled hole in the mating part. The hole is 0.001 to 0.002 in. larger in diameter than the pilot. With the parts so positioned, welding current and force are applied and the weld is made. Proper alignment of electrode faces insures that there is no assembly misalignment during welding, and the sides of the cone center the parts during the squeeze time of the weld sequence. Figure 1 shows a cross section of the mating parts before and after welding. Steels used are plain carbon – C-1015 and below.

An example of an assembly made by this process is shown in Fig. 2. The two side wings

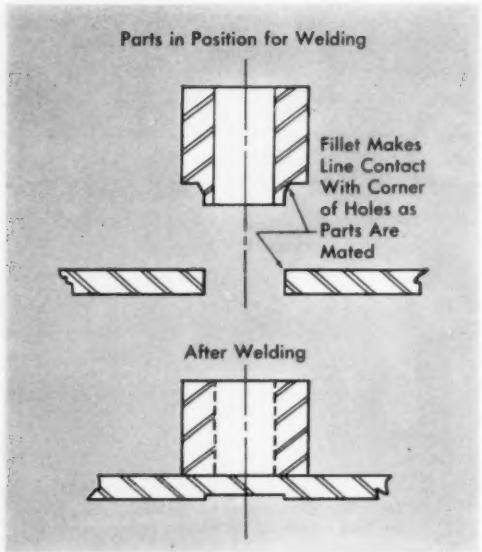

Fig. 3 – Hub Projection Welding, Similar to Pilot Projection, Is Useful in Joining Bushings and Hubs to Plates

are welded to the back section in one operation. The bottom bar is then welded to the back section in a second operation. There are no locating devices on the welding dies except those to hold the parts upright until the dies close. The pilots effect the location and the projections effect the weld. The welding dies use ½-in. diameter tips with R.W.M.A. Class 10 (or comparable) electrode facing.

Hub Projection Welding – Following the successful development of pilot projection welding as a fastening method, we adapted a second and equally useful variation of projection welding known as hub projection welding. Figure 3 shows the cross section of the hub projection version of projection welding. Materials used in this process for hubs or bushings can vary from C-1010 to C-1213. Our experience has indicated that carbon should be kept below 0.15%. Resulphurized free-machining grades are usually all right. The manganese-type free-cutting steels are troublesome. Stampings in flat stock should be in the C-1015 grade or lower. Higher carbon steels can be projection welded but require special attention and setup.

Applications

Forge Welding High-Strength Aluminum and Magnesium Alloys

*By L. A. COOK and D. G. SHAFER**

THE PRINCIPLES OF FORGE WELDING some nonferrous alloys (lower-strength aluminum alloys, for example) are well known. Much of this welding has taken place at room temperature or above the recrystallization temperature of the alloys involved. However, until recently there has been little forge welding of high-strength aluminum and magnesium alloys at warm forming temperatures which are high enough to allow the necessary flow in forge welding, but low enough to avoid overaging or reduction in physical properties of the metal being worked.

Butt Welds – It has now been well established that with relatively simple equipment and control techniques even the high-strength nonferrous alloys such as ZK60A-T5 magnesium alloy and 7075-T6 aluminum alloy can be forge welded with joint efficiencies of 90 to 100%. Applications, however, are limited to butt welds or modifications of butt welds.

A number of companies and government agencies have considered the process for such applications as lightweight bridge construction, longitudinal seams in large containers for missiles, butt welding of heavy rings for missile and other applications and butt welding high-strength aluminum or magnesium alloys for automotive and truck rims. It may also be feasible to use forge welding for lightweight armor plate made of high-strength alloys.

Future Growth – Many of the potential appli-

*President and Executive Vice-President, respectively, Ravens-Metal Products, Inc., Parkersburg, W.Va.

cations of the process require a rather expensive tooling and large capital outlay for equipment and presses. However, joints may be made rapidly, with high quality and with a minimum of a metallurgical notch across the bonded area since the joint area consists of wrought material and no cast structure is obtained. Neither are foreign particles nor inclusions introduced into the weld during the welding operation.

Generally speaking, applications for forge welding will increase in those areas where a high-strength, lightweight structure is imperative, and where the volume of production or need for the component justifies a substantial capital investment in dies and equipment.

Applications

Electron Beam Welding: Emphasis on Precision and Freedom From Contamination

*By MARSBED HABLANIAN**

ALTHOUGH IT IS NOT YET a conventional production process, electron beam welding has come a long way in the last few months. It's no longer looked on as a laboratory curiosity or a last-resort process to be used only for fabricating critical assembles – such as nuclear fuel elements – out of reactive and refractory metals. Besides being used increasingly to join these hard-to-weld metals – generally for missile and nuclear purposes – it is now being applied to less exotic metals in the production of electronic elements and sensitive mechanical control devices and is even being considered for such everyday products as milk cans.

Welding is done in a high vacuum – usually a millionth of atmospheric pressure or lower – with heat produced when the work is struck by a beam of electrons. These are generated from a hot tungsten or tantalum filament, accelerated by a voltage, which in different types of equipment may vary from 5 to 150 kv., and focused electrostatically or electromagnetically (or both) into a beam.

Much of the early interest in the process stemmed from its ability to assure welds which were much freer of contamination than possible by shielded arc welding, the best process then available for joining exotic metals. High vacuum contains only a small fraction of the active gases present in even the most highly purified inert gas, and the electrons represent a "pure" source of heat which eliminates any chance of metallic contamination from an electrode. It was also found that if the feed rate is not too high the combination of intense heat and low pressure cleans up many surface impurities, with the result that the weld area is free from porosity and inclusions. Manufacturers of evacuated products and sealed containers were delighted to discover that electron beam welds are inherently vacuumtight, again providing that a proper feed rate is used.

However, except for applications in which freedom from contamination justified any means, early acceptance of electron beam welding was slowed by the high cost, complexity, and inflexibility of the equipment initially available. The recent introduction of several "second generation" welders, which are priced within the reach of most fabricators, easy to operate, and extremely flexible, has already resulted in increased use of the electron beam process, and promises much broader future applications.

For example, now available in the $13,000 to $17,000 range are welders in which the accelerating voltage can be easily varied from 0 to 30 kv., beam current from 0 to 200 milliamp., spot size from 10 mils to 6 in., and focal point from 1 to 12 in. By adjusting the spot size, it is possible to get more than 4 to 1 depth-to-width ratios in stainless steel, or to postweld anneal a large area. Such units employ an

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Fig. 1 – Butt Welding Tungsten Cylinder in Medium-Voltage Electron Beam Welder

Fig. 2 – Etched Cross Section of "Continuous Spike" Weld in Type 347 Stainless Steel

electron beam generating source, or "gun", containing an accelerating anode and a variable electromagnetic focusing coil, so that the region between the gun and the work is field free. As a result, the direction of the electrons is not affected by the geometry of the work. An additional advantage is that arcing between high-voltage elements, a frequent nuisance with early welders, is no problem.

Freedom From Contamination – Heavier-thrust rocket engines and improved nuclear reactors are requiring larger assembles fabricated of high-temperature and reactive metals. Because failure of such assemblies can have expensive and disastrous results, and because minute quantities of gas can seriously impair the physical properties of these metals, electron beam welding is almost essential. According to one user, "Electron beam is to reactive metals what heliarc is to stainless steel". Also, the growing importance of close chemical control in electronic elements and solid-state devices should lead to the use of electron beam fabrication, as should studies of the properties of extremely pure metals such as corrosion resistant iron.

Because electron beam is the only convenient fusion welding process to work in high vacuum, and because, with proper feed rates, it assures a vacuumtight joint, it has obvious advantages for fabricating products which are to be evacuated. For instance, Metal Bellows Corp., Newton, Mass., is using an electron beam welder to cut costs and rejects in the production of an evacuated precision bellows used for altitude compensation in aircraft instruments. Formerly, an exhaust tube was welded into the bellows, which was then evacuated and the tube pinched off and welded. Now the tube has been replaced by a hole, and the bellows is evacuated and sealed in one easy operation. The weld is structurally strong, and there is no protruding tube stub to worry about. Manufacturers of vacuum tubes and evacuated electronic assembles are now investigating similar applications.

Precise Control – Some enthusiasts feel that the precise control of heat into the weld zone which is possible with the latest equipment will prove as important as freedom from contamination in popularizing electron beam welding. The ability to vary both total power and power concentration continuously and independently permits single-pass welding of pieces with varying cross sections. By focusing the beam to a fine spot, depth-to-width ratios of more than 4 to 1 are possible. (High-voltage equipment, costing several times as much, can produce depth-to-width ratios of 10 to 1 or greater. The heated area is so narrow, however, that extra

care is needed to make sure it occurs at the junction of the two pieces.) High depth-to-width ratios make feasible a process which some call "continuous spike" welding. In this technique, a plate is fitted to the lands of a channeled piece and the weld made through the plate into the land. "Continuous spike" welding makes it possible to construct high-pressure fluid transfer lines of any desired configuration within a structural member. This should prove useful in turbines, rocket engines, or nuclear reactors. This type of weld may also find application in heavy honeycomb construction or fabrication of chemical process equipment.

High depth-to-width ratios also minimize distortion, so that it is possible to reduce costs by finish machining components before welding instead of re-machining after welding. It is also feasible to weld heat sensitive assemblies such as electronic devices or brazed subassemblies. On the other hand, there are often times when a wider spot is desirable. For instance, titanium liners have been successfully welded into heavy copper tubes by enlarging the spot and dividing it between the two metals so as to bring each to its melting point. The same procedure can be used to join a thin section to a thick one. A broader spot also permits using a filler wire or rod to seal a gap between two faces. As already mentioned, the beam can be defocused to anneal the weld and surrounding area after the weld is completed.

The field-free characteristic of the beam opens up interesting possibilities, since it makes it easy to get precision welds at the junction of two surfaces meeting at an acute angle. One manufacturer of stainless steel milk cans is investigating the possibility of using electron beam welding to make an internal weld between the bottom and the can walls to eliminate any crevices in which bacteria could breed. Odd-shaped cavities in metals that are hard to broach can be made by milling sections and then welding them together, with all but the final weld being made internally.

Since the beam can weld at the bottom of a narrow groove, machining time required to make deep narrow crevice-free slits can be substantially reduced either by joining two sections or by welding a bottom piece to each of the side pieces. Even some nonconductors can be fusion welded under vacuum.

The above applications are representative of the kind of work for which electron beam welding is being used or considered. As more fabricators – especially those using the new high-performance materials and requiring precision welds – learn more about the advantages of present-day equipment, many other uses can be expected.

Applications

Button Welding . . . a Low-Cost Production Tool

*By J. J. CHYLE**

BUTTON WELDING IS a new designation given to a low-cost welding process which is used in the fabrication of light-gage materials and is replacing other conventional welding processes in many applications.

This method uses the consumable metal-arc process and carbon dioxide gas for making single spot welds. The wire electrode arc melts through the top plate and penetrates into the lower member, leaving a weld reinforcement on the top which appears as a round button. For various applications and configurations, the gas cup or nozzle can be designed by shaping the end to the desired contour. It can be readily removed and the unit converted to the standard semi-automatic consumable arc process. A precision timer controls the length of the welding cycle, thus producing consistent welds without requiring special operator skill or training. Two separate processes can be used, either CO_2 shielding gas with reverse polarity, or argon (5% O_2, 95% Ar) shielding gas with straight polarity.

Button welding with CO_2 gas is generally referred to as a "burn-through" method. The inert-gas process is usually used with the edge-

*Director of Welding Research, A. O. Smith Corp., Milwaukee, Wis.

Table I – Procedures for Button Welding

Stock Thickness	Current	Voltage	Weld Time*	Wire Consumption†	Average Shear Load‡
3/32 to 3/32 in.	320 amp.	36	60 cycles	3 15/16 in.	3740 lb.
1/8 to 1/8	380	42	50	4 9/16	4650
3/16 to 3/16	440	46	80	8 5/8	6030
1/4 to 1/4	580	43	105	14 3/4	12,925

*At 60 cycles per sec.
†Per button (1/16 in. CO-86).
‡Ultimate load (average value, 10 specimens).

type button weld, and the process can be called a precision-timed fillet button weld. This method produces much shallower penetration and is used on extremely thin stock (0.032 to 0.060 in.).

For either process, the operator need only place the lightweight gun in position, pull the trigger, and hold it until welding is completed. Timing is started when the electrode touches the work and the arc is initiated, and the weld continues until the preset time has expired. Since the gas cup or nozzle completely covers the area to be welded, the operator need only use tinted or colored safety glasses.

Fig. 1 – Cross Sections Through Button Welds in Typical Automobile Applications. Surface condition of parts and gap between them (up to 1/16 in.) is not critical

Stock Thickness – The burn-through button welding process can be used on stock thickness ranging from 0.035 to 0.250 in. The complete button welding package consists of constant potential power source, wire drive unit, cycle timer, and button welding gun, hose and cable assembly. The size of button and depth of penetration can be changed by varying the wire feed speed or amperage, the arc voltage, and welding time cycle. Gap variations from tight fit to 1/16-in. gap do not materially affect the appearance or shear strength of the button weld. Typical welding procedures or schedules for various stock thicknesses and their relative shear strength are given in Table I.

The ultimate shear strengths as shown in Table I are comparable to shear strengths obtainable with the resistance spot welding process on the same gage and material. Preliminary results indicate that the fatigue strength of button welded assemblies is also comparable to that obtained with resistance spot welds in similar thicknesses.

Production – Button welding can be adapted to many production applications where riveting, manual arc welding, or resistance spot welding are being used. Its speed, consistency, and versatility make it a good production tool. The surface condition of the steel does not seriously affect the quality of the weld, as it does in resistance welding. In some applications, satisfactory button welds have been obtained when attaching parts to a main member which has already been painted. Figure 1 shows typical cross sections of button welds of several production applications.

The process is also used for tacking together heavy-gage sheet and plate instead of using the manual arc welding process. When the height of the button must be limited, the process can be applied as a plug welding operation by punching or drilling a hole in the top member.

Fig. 2 – Cover Plate on Formed Channel Was Attached With Two Button Welds (See Fig. 3)

Fig. 3 – Simple Operation of Button Welding and Its Ability to Produce Quick Welds Make It an Excellent Production Tool

This is preferred for heavy-gage plate material.

Economics – Button welding is a low-cost operation. Cost of carbon dioxide ranges from ½ to 1½¢ per cu.ft., and a flow rate of 30 cu.ft. per hr. is required during welding. Wire consumption (see Table I) for button welding ⅛-in. stock, using 1/16-in. diameter wire, is 4 9/16-in. per button, or about one-tenth of a cent per button. The welding time used for this button is only 50 cycles or 0.8 sec.

The rapidity with which button welds can be made usually results in marked direct labor saving. A typical example of the saving that can be realized is shown by a production application where three men using CO_2 button welding produce 400 more pieces per day than six men previously produced by manual arc welding using coated electrodes.

A 1/16-in. diameter wire is used on stock thickness of 3/32 in. or more; a 3/64 in. wire is used on the thinner gages. The CO-86 (triple deoxidized) electrode or wire is used on all applications. It eliminates the necessity of cleaning or washing the surface of the stock. Figure 3 is a view of a production application of CO_2 button welding in which a cover plate is being welded to a formed channel section. Figure 2 shows the finished part.

Applications

Automatic Tube Welding Increases Reliability, Lowers Reject Rate

*By L. H. HAWTHORNE**

IN THE FIELD OF ATOMIC POWER the demands for higher efficiency at higher operating temperatures and pressures and the stringent demands for condensate purity have greatly increased interest in high-quality tube-to-tube sheet joints. Welding of these joints seems to supply the only adequate solution to this problem where positive and permanent leak-tightness is a definite requirement.

The installation of tubes to tube sheets in

*Manager, Welding Service, Research Dept., Revere Copper and Brass, Inc., Rome, N.Y.

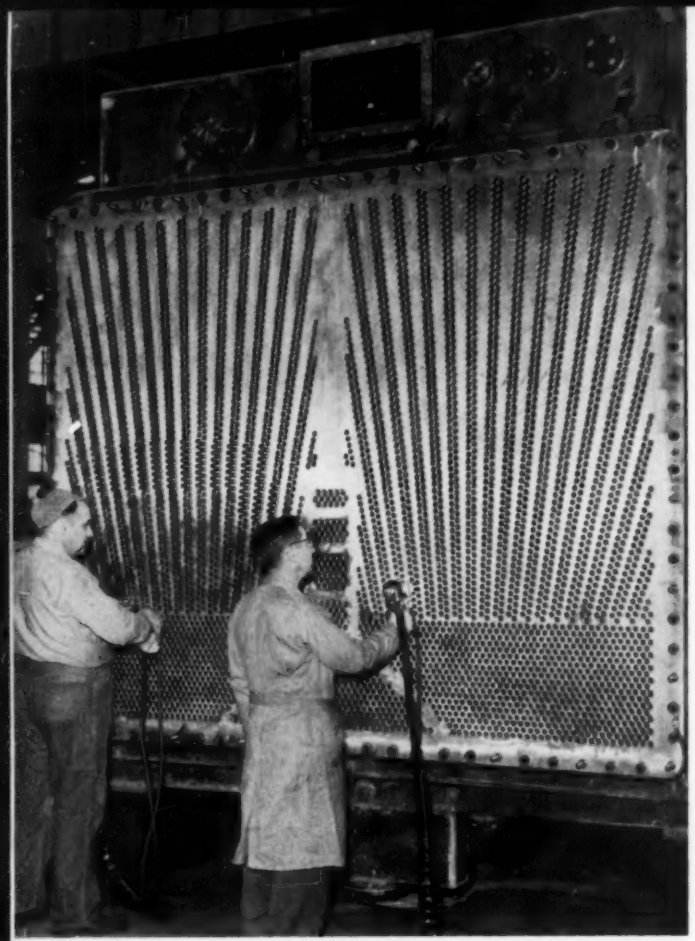

Fig. 1 — Automatic Tube Welding Gun Took Much of the Guesswork Out of Critical Tube-to-Tube Sheet Welds in Condensers for N.S. Savannah, Our First Atomic-Powered Surface Ship. Reject rate was only 0.46% in about 15,000 welds

such a manner that joints of high integrity and consistency can be obtained is a problem with which designers and fabricators have been faced for many years. Manual welding techniques have been successful to a degree but because of the human element involved, it is impossible to consistently predict the quality and strength of joints thus produced.

Gun Developed — The automatic tube welding gun developed in our Research Laboratory was designed to solve these problems. This equipment employs what is basically a gas-shielded tungsten-arc process implemented in such a manner that the human element in the operation is not a factor in welding quality. The control circuitry is so designed as to provide in the production of a tube-to-tube sheet weld the following sequence of operation: The weld area is prepurged with the shielding gas and the arc is initiated. The torch then travels automatically around the periphery of the tube through one full revolution plus 20° to reweld the start area of the weld. Arc decay is controlled so that the welding current is reduced to a level low enough that crater cracks or pipes in the crater area will not result when the arc is broken. The torch then returns to the home position after the arc is broken and the electrode and weld area are purged to prevent oxidation.

These operations are completely automatic and the operator has no control over the function of the equipment once the proper adjustments are made.

Accuracy of the arc path around the tube periphery is maintained within ± 0.005 in. independent of inaccuracies of tube sheet drilling.

This equipment, although primarily designed for use in the welding of material employed in the fabrication of surface condensers, has proven useful on many other materials. In addition to its use on nonferrous alloys for surface condensers, the equipment is used extensively on stainless steel and ferrous materials. In short, this method of welding tubes to tube sheets can be employed successfully on any material or combination of materials which are compatible for fusion welding.

The speed with which welding is accomplished is such that welding usually can be done with the tube sheet in the vertical position. This eliminates the need for positioning a large vessel — an important factor to most fabricators.

When satisfactory joint designs are employed, weld penetration equal to or slightly greater than tube wall thickness can be obtained where tube wall thickness does not exceed 10 Birmingham Wire Gage. Weld strengths obtained are in most cases equal to or greater than the minimum required tensile strength of the weaker of the materials involved.

Critical Application — Figure 1 shows the gun in use during fabrication of the main condenser for the N.S. Savannah, the United States' first nuclear-powered surface ship. The equipment was used to weld both the main and auxiliary condensers to be used on the Savannah at Ingersoll-Rand Co., Phillipsburg, N.J. About 15,000 welds were required. Of these only 69 defective welds were found by testing with air pressure, with helium and halide equipment followed by dye penetrant and hydrostatic tests. This represents a reject rate of only 0.46%. Repairs were effected by simply rewelding with the gun.

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CORRESPONDENCE

The Earliest Days of Precipitation Hardening

CORVALLIS, ORE.

In an article under the above title starting on p. 79 of the April issue of *Metal Progress*, W. A. Mudge recapitulates some of the history of duralumin and he tries to locate this invention in the context of previous art. Curiously enough, he, as well as all past reviewers of Wilm's invention, misses the contribution of Conrad Claessen who worked in the same laboratory as Wilm and gave his name to three patents that cover partly, if not completely, the composition and the thermal treatment of duralumin. The dates referring to various stages in the development of this alloy are given in the table herewith.

Claessen, according to his first two patents (No. 2 and 3 in the table), studied binary Al-Cu alloys which he quenched and stored. This was in 1903, 1904 and 1905, at least two years before Wilm's first patent (No. 4). Their mechanical properties improved in the course of weeks by aging. If, after quenching, he had reheated them for a while to 100 to 150° C., he would have observed age hardening within a few hours. However, at that time he did not test the magnesium bearing Al-Cu mixtures, which age in 24 hr. His leading hypothesis in these experiments was that aluminum alloys might be hardenable like steel, by quenching.

Did Wilm work with or under Claessen at Zentralstelle laboratories? The former supposition seems probable because an American patent (No. 4) concerning substantially the heat treatment recommended by Claessen in a German patent (No. 3) appears two years later in the name of Wilm. Nevertheless, it is fair to credit the invention of duralumin to Wilm, who was a trained metallurgist, while Claessen, as seen from his many patents during the same period, experimented as a chemist with explosives. Yet Claessen obtained a U. S. patent in 1911, in his name, on the duralumin composition (No. 8), which would indicate that both inventors worked for almost ten years side by side, if not closely together, on the duralumin problem.

The thoughts of Wilm, judging from some of his patent specifications (No. 5, 6 and 7), were somewhat confused as to the effect of his thermal treatment, since he suggested either to quench, or to cool slowly from a temperature of about 450° C. The latter could reasonably apply only to very thin sections, which could be air cooled rapidly enough to bring about a combined solution and aging effect. Wilm finally de-

Chronology of the Duralumin Invention

Item No.	Inventor and Patent	Date	Summary of the Invention
1	Wilm	1901	Joins at the age of 32 the Zentralstelle laboratories where Conrad Claessen is already active.
2	Claessen G.P. 170,085	1903	Annealing Al alloys at a specific temperature followed by quenching to improve strength and elongation.
3	Claessen G.P. 181,737	1905	Addition to G.P. 170,085, specifying accurate quenching temperatures.
4	Wilm U.S. 868,383	1907	Claims similar thermal treatment to the one disclosed by Claessen's G.P. 181,737.
5	Wilm G.P. 204,543	1907	Alloy composition: Less than 2 Mg, up to 5 Cu; to delineate field of Wilm's alloy against that of "Magnalium." Thermal treatment of these alloys.
6	Wilm G.P. 244,554	1909	Thermal treatment of Mg-bearing Al-Cu-Mn alloys, annealed after working to above 420° C., quenched or left to cool slowly, to improve properties automatically.
7	Wilm Br. P. 6485	1910	Heat an alloy of Al containing Mg, above 420° C. and let it improve spontaneously.
8	Claessen U.S. 995,113	1911	Covers duralumin composition with 4 Cu and 0.25 to 0.5 Mg. Similar to No. 5, Wilm.
9	Wilm U.S. 1,083,903	1914	Duralumin composition and thermal treatment of the alloy.
10	Wilm U.S. 1,130,785	1915	Alloy with 0.5 Mg, 3 Cu and 1 Mn, the Mn added to improve corrosion resistance.
11	Wilm	1919	Becomes a farmer at the age of 50.

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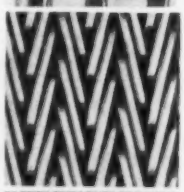

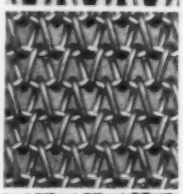

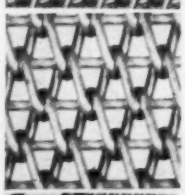

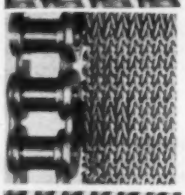

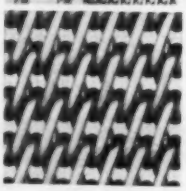

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Precipitation Hardening...

fines his invention in his U. S. patents of 1914 and 1915 (No. 9 and 10) in which he indicates the best alloy, its correct heat treatment and the role of manganese. He retired in 1919 at the age of 50 to become a farmer. His invention had not brought him riches.

It would be of interest to establish the historical truth of the relations that must have existed, at least in the early years, between Claessen and Wilm, as indicated in their alternate names on the patents. One might scrutinize the government and company documents and files still available, especially those of the Patentamt and of the Durener Metallwerke, and by interviewing any survivors among Zentralstelle's staff of the World War I era. If the names on the letters of patent are those of the true inventors, Wilm's rights are entirely contained in, and dependent on, Claessen's broader and prior claim (No. 2, 3 and 8). Even if it was so on paper, this should not becloud the fact that it was the metallurgist Wilm and not the chemist Claessen who, by his work, gave us duralumin, inaugurated precipitation hardening, and unconsciously opened a new and vast branch of physical metallurgy.

W. J. KROLL
Consulting Metallurgist

AUTHOR'S REPLY: When I wrote my paper on "The Earliest Days of Precipitation Hardening", I hoped that metallurgists who had special knowledge in their fields would contribute their information so that some day the *complete* story of precipitation hardening might be told.

I do not wish to enter into any Wilm vs. Claessen controversy. The record of Claessen appears to have been established. If he had done what Dr. Kroll proposes a half century later, something different might have resulted. But he did not.

Claessen, like Wilm, made interesting and valuable observations, but they did not understand what they had observed. Wilm wrote, about 1911, "I can speak only of the effect of the hardening process on aluminum alloys . . . without being able to give an explanation of its nature".

I agree with Dr. Kroll's first state-

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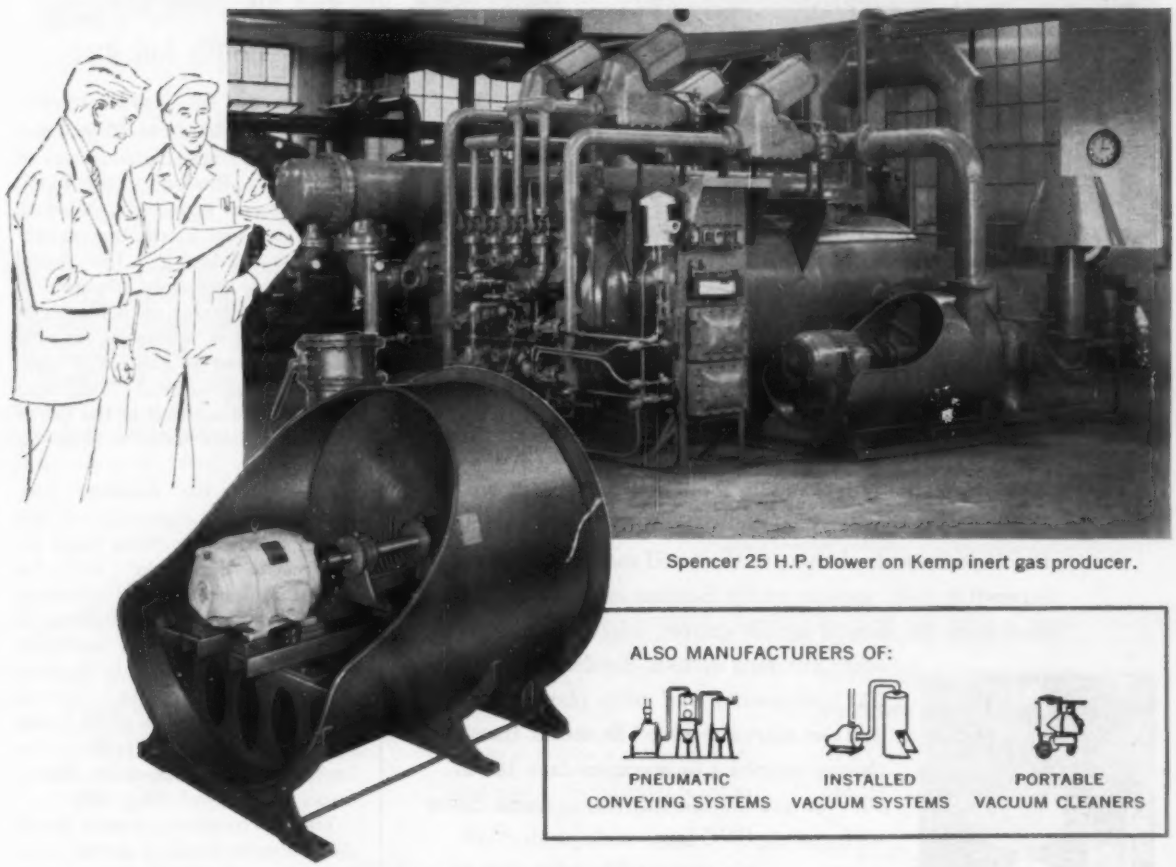

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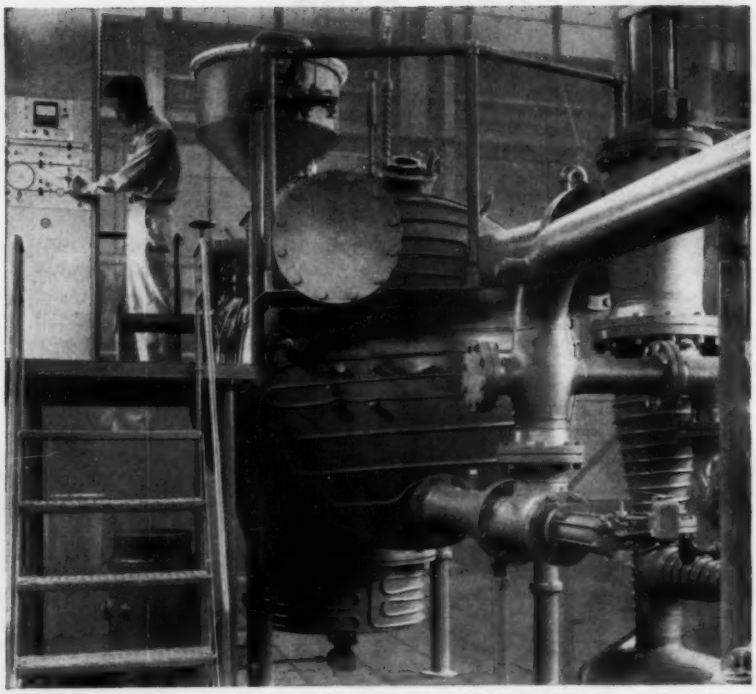

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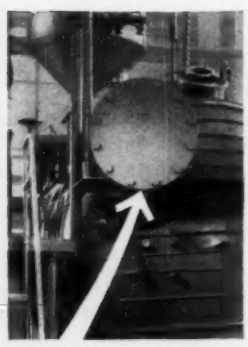

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Circle 442 on Page 48-8

Precipitation Hardening...

ment that "Wilm gave us Duralumin", but I disagree with his second statement that Wilm "inaugurated precipitation hardening and unconsciously opened a new and vast branch of physical metallurgy".

First, it was Paillard who inaugurated precipitation hardening approximately 20 years earlier than Wilm. Second, it was Merica, Waltenburg and Scott who explained the phenomenon and thereby opened a new and vast branch of physical metallurgy, *consciously and knowingly*, not unconsciously.

W. A. MUDGE

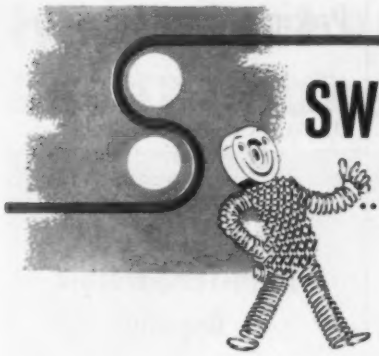
TOLEDO, OHIO

The recent article in *Metal Progress* entitled "The Earliest Days of Precipitation Hardening", by W. A. Mudge, seems to include almost all of the historical information on precipitation hardening. The dental profession is especially interested in the heat treatment of noble metal alloys and it is interesting to note that the patent by Paillard as early as 1886 was entitled "Palladium Alloys". The increase in the use of palladium alloys today in dentistry is noteworthy.

Apparently the Russians were working on the hardening of soft metals shortly after Wilm made his discovery of "duralumin" (1913) for in 1916 the effect of heat treatment on gold-copper alloys was discussed by Kurnakow, Zemczuzny and Zasadatelev in the *Journal* of the Institute of Metals, Vol. 15, p. 305. This was brought to the attention of the dental profession by Oscar E. Harder in the *Journal* of the American Dental Assoc. in 1923, Vol. 10. p. 869.

The heat treatment of many dental alloys of noble metals is routine practice today. It often includes a slow cooling throughout the hardening range after casting; occasionally this process is refined to include a solution treatment followed by either a slow cooling or a constant temperature treatment to produce the desired properties.

A number of years ago alloys were in use where such treatments could produce very brittle dentures, and "heat treatment" was severely criticized for this reason. Today the alloys are so formulated that there is



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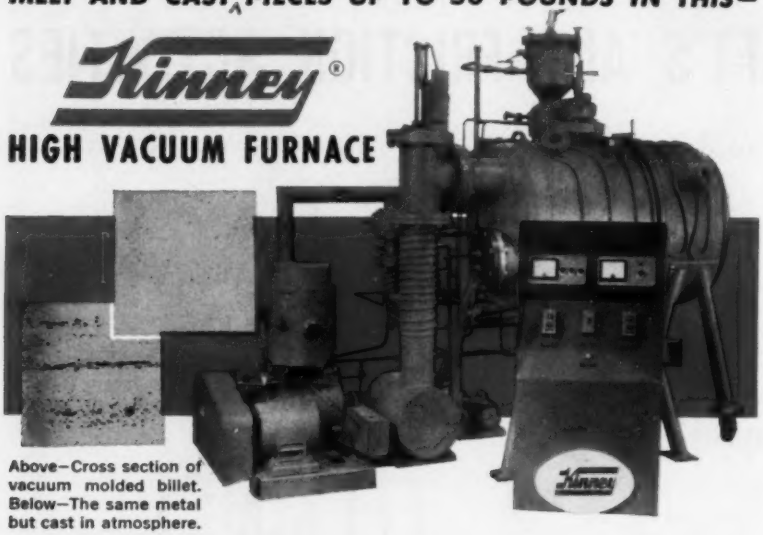

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Precipitation Hardening...

little danger of excessive brittleness, although the heat treatment cycle should always be controlled.

JOHN S. SHELL
Research Director
Ransom & Randolph Co.

High-Temperature Brazing

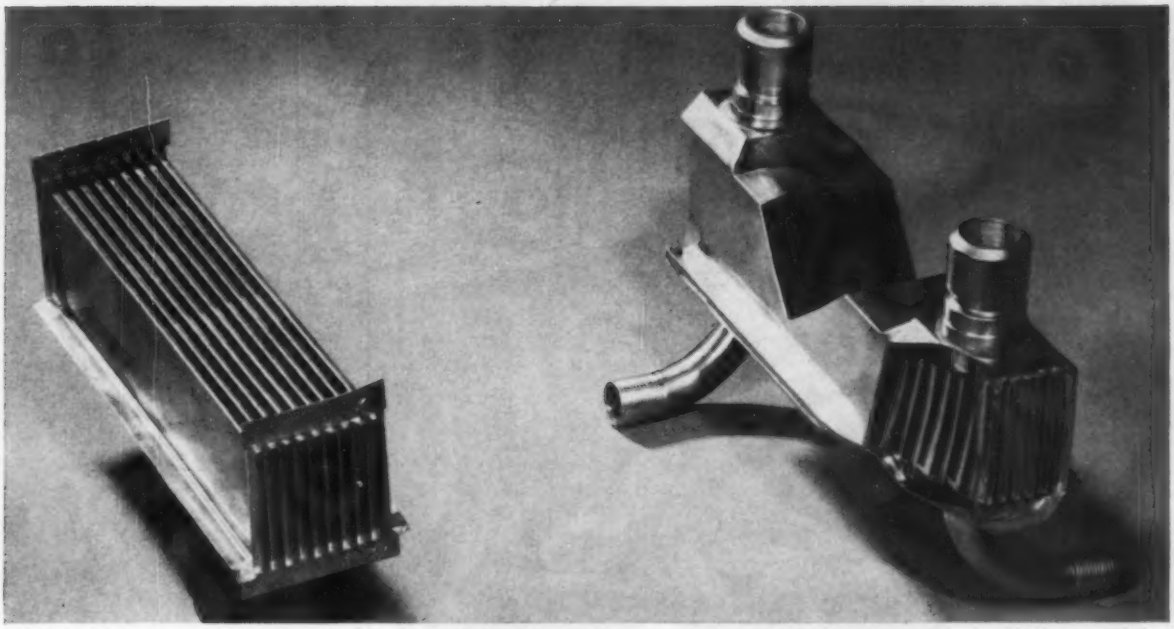
QUEHANNA, PA.

In "High-Temperature Brazing Experiments", published last February in *Metal Progress* (p. 95 to 97), R. R. Ruppender severely criticizes the existing methods of evaluating experimental data, the interpretation of their meaning, and the conclusions drawn. Unfortunately, the author does not disclose the chemical composition of filler metals A and B, nor does he state the type of parent metals or the joint design used. These factors determine the optimum strength to be expected. If the author puts down 42,950 psi., he gives the impression that he can determine his values to four significant figures. Further, when he gets 23,050 psi. for his next value, he should investigate his technique for lack of accuracy before going any further. Such a wide variation is suspicious. Contrary to the author's statement on p. 97, the skill of the operator and the type of equipment can make a lot of difference in the results obtained. Also, filler and base alloy specifications might be "fixed", but the alloys themselves change sometimes radically in the brazing process. The so-called independent variables such as time, temperature, heating rate and clearance cannot be kept constant for various filler metals which require different brazing temperatures.

No customer would like to make up more joints to obtain a possible failure. Instead he prefers all joints to be above a certain strength limit. In most brazing data, only two of the figures are significant, not to be confused with the sensitivity and accuracy of the testing machines. No specifications for filler brazing alloys mention joint strength at all as yet. Some day a brazing or soldering alloy will have the joint strength guaranteed to be at least a certain percentage of the parent metal strength.

In summary, the basic concepts

Heat exchanger of Armco Stainless saves money, helps save lives



Blood and water are separated by the strong walls of the core (left) made from .005-inch Armco Stainless Steel. At right is a cut-away showing core in place in the case of Armco Stainless.

This tiny stainless heat exchanger made by the Surgical Instrument Company (Joseph A. Chyba and Sons), Baltimore, Maryland, protects human lives. During open-heart surgery, it cools the patient's blood to a point that surgeons consider safer. Even though it's used only once, it saves money compared with permanent types.

High tensile strength of Armco 18-8 Stainless Steel permits use of .005-inch thick core walls. These thin-gage stainless walls make the unit more efficient. In addition, Armco Stainless for case and tubes results in a unit that can be guaranteed sterile and pyrogen-free, and won't corrode in storage.

LOW IN COST

This unit costs less than a half-pint of blood, about $\frac{1}{20}$th as much as the cheapest of non-disposable units. It weighs only 7 ounces, compared to about 25 pounds for a permanent type. Moreover, the larger units take about a pint of blood to prime them and require thorough cleaning after use. This disposable unit can be used once, then thrown away at a saving for blood alone.

As in this unique heat exchanger, Armco Stainless Steels—sheets, strip, bars and wire—in more than 60 analyses and a broad range of gages, sizes, finishes and conditions, offer specific opportunities for savings and improved performance in thousands of products. Perhaps yours is one of them. Just mail the coupon for complete information.

Use the STEELMARK to identify quality steels in the products you make

Stainless Steel

New steels are born at Armco

ARMCO STEEL CORPORATION
2170 Curtis Street, Middletown, Ohio
Send your catalog, "Armco Stainless Steels"

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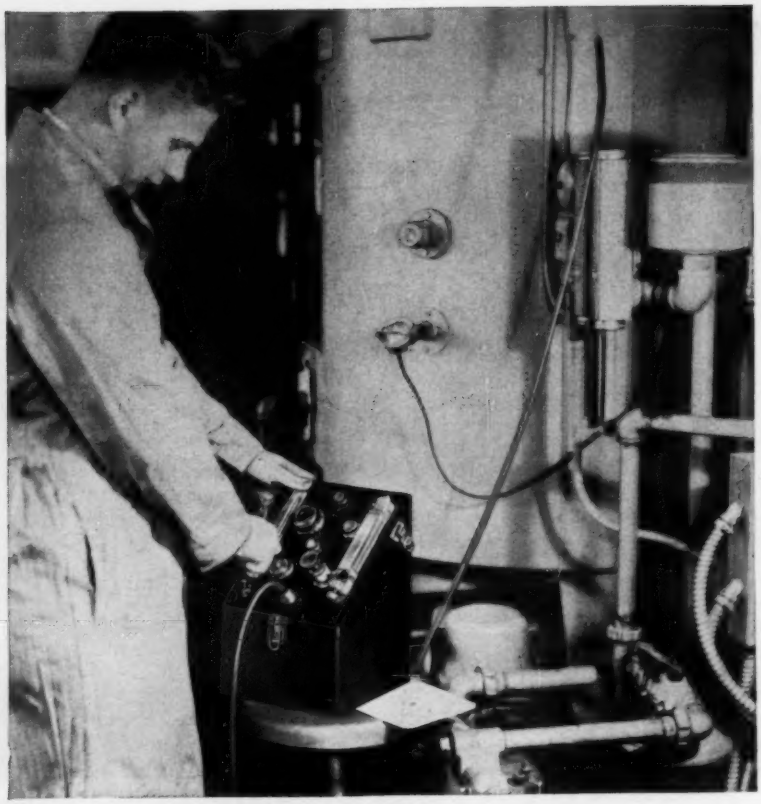
ARMCO STEEL

ARMCO

Armco Division • Sheffield Division • The National Supply Company • Armco Drainage & Metal Products, Inc. • The Armco International Corporation • Union Wire Rope Corporation

Circle 445 on Page 48-B



Necessary for controlled production in heat treating

Alnor DEWPOINTER®

for Determining Carbon Potential

The atmospheric condition in a heat treating furnace is accurately indicated by the Alnor Dewpointer. A sampling tube from the furnace connected to the Dewpointer makes it possible to check the carbon potential of furnace atmosphere almost instantly at any time during the process.

The Dewpointer can easily be disconnected and moved to other furnaces. The consistency of accurate readings by different operators on different furnaces is evidence of the reliability of the Dewpointer and the ease of operating.

To make a test, a sample taken from the furnace is put under pressure in the observation chamber and then released quickly to atmospheric pressure. If the expansion cools the gas below its dew point a distinctive fog is observed. This is repeated until the fog vanishing point is reached and the end point determined on the pressure ratio gauge. The exact dew point is indicated immediately. The model 7000-U Dewpointer is priced at $410.00.

Write for bulletin 2051

Alnor INSTRUMENTS

ILLINOIS TESTING LABORATORIES, *Inc.*
Room 523, 420 N. LaSalle St., Chicago 10, Ill., U.S.A.

Circle 446 on Page 48-E

Brazing . . .

and lucidity of the article deserve commendation for emphasizing the usefulness of statistics in bringing reliability into data evaluation, but the data should lie within an expected range of accuracy. The example used in the article is just not very closely related to the realities.

KARL M. WEIGERT
Senior Research Metallurgist
Curtiss-Wright Corp.

AUTHOR'S REPLY: The alloys used in my article were fictitious and the data synthetic but the problem was real and was taken from published data, other than my own. The example *is* very closely related to the realities of brazed joint testing.

Everyone knows that much scatter in data makes for insensitivity. In this way, we apply a statistical concept intuitively or tacitly. My article suggests that we can put teeth into this concept and put it on the quantitative basis that modern technology demands.

Suppose you had several dozen tensile observations of a certain steel. You want to test a new heat treatment which you hope will improve the yield strength with negligible sacrifice in elongation. How much yield improvement do you want to detect? One psi.? One hundred? In view of the expected scatter, how large a decrease in average elongation will you accept as being real? How many tests should be run? What is the power of your experiment to detect a change of a given magnitude? If you want to detect an improvement as small as 10,000 psi., will you be satisfied with a 50-50 chance of success? These are statistical questions requiring statistical answers. They are also engineering questions. Therefore, engineering questions of this kind require statistical answers.

The metallurgist sees a battleship as a noble stack of steel; the admiral sees it as a weapon, the accountant as a monstrous expense. In a similar way I believe Dr. Weigert and I are looking at the same general problem and seeing different things, all of which are important. Through such discussion we get to study the views of another and consequently enlarge our own individual spheres of understanding.

R. R. RUPPENDER

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quality controlled, trouble-free:

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Locust 7-5129

PITTSBURGH 24, PENNA.
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Capitol 7-1404

ROCHESTER 4, NEW YORK
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WHITING, IND. (CHICAGO)
Whiting: Whiting 826
Chicago: Essex 5-5000

IN CANADA: Federated Metals Canada, Ltd. Toronto, Ont., 1110 Birchmount Rd., Scarborough, Phone: Plymouth 73246

Montreal, P.Q., 1400 Norman St., Lachine, Phone: Melrose 7-3591

Circle 447 on Page 48-B

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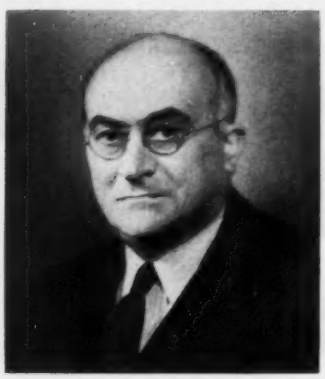


W. Spraragen

W. SPRARAGEN (Bill to numberless acquaintances) has retired from the position of director, Welding Research Council, and has been succeeded by **K. H. Koopman**. Spraragen has spent his entire professional life in cooperative research in welding, being appointed in 1918 a project director of the Welding Research Program of the World War I "Emergency Fleet Corp.". In 1920 the American Welding Society and the National Research Council merged their similar investigations in the "American Bureau of Welding", and Bill became its secretary — a post he continued when the name of the activity was changed in 1935 to "Welding Research Council". Ten years later he became its director. He also served for many years as secretary of the American Welding Society.

Three new regional sales managers have been added to the American Society for Metals staff: DAVID H. BROOKS, DAVID A. LEWIS and WILLIAM A. GRAHAM (shown below, left to right, discussing *Metal Progress* with Editor Gray, second from right).

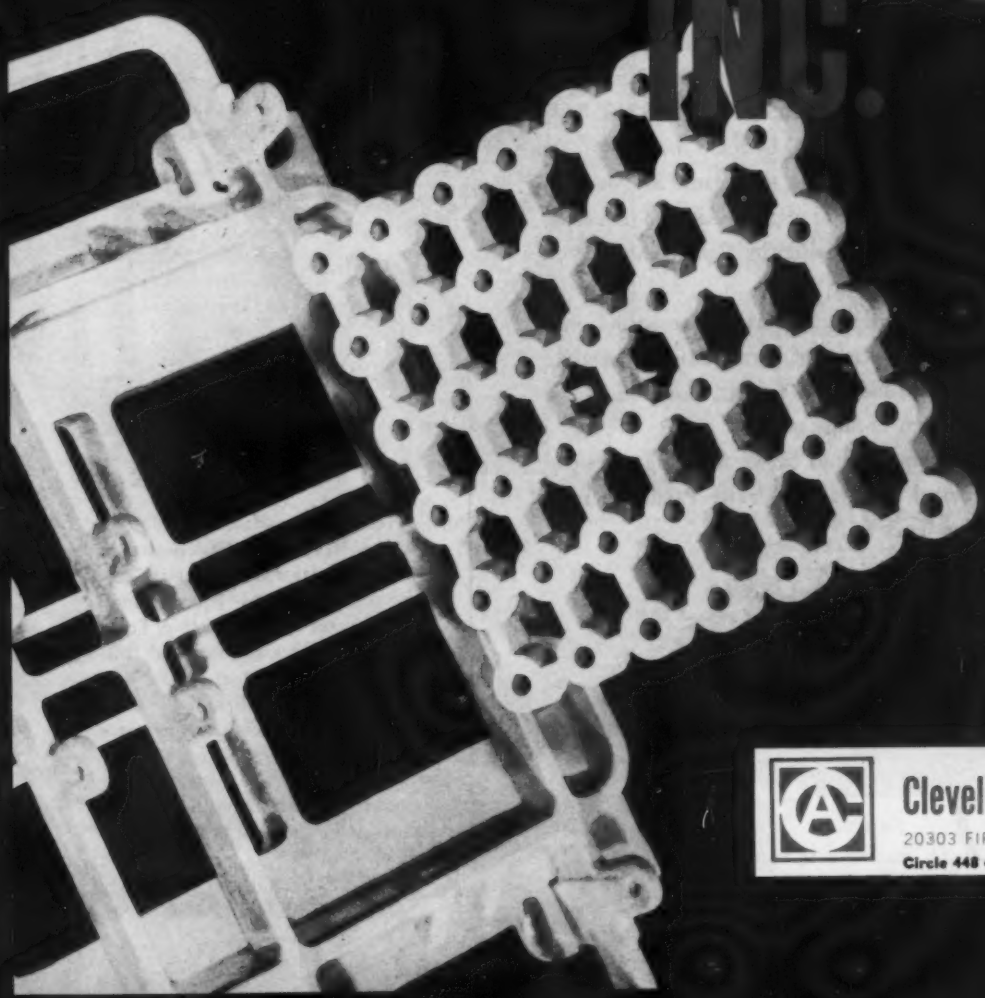
David Brooks joins John B. Verrier, Jr., New York regional manager, and Fred Stanley, Philadelphia regional manager, in the New York office where he will handle the newly created New England territory. His background includes six years in advertising with Bridgeport Brass Co. and Cunningham & Walsh, Inc.

The expansion of the Cleveland-Pittsburgh operations of the Society sales staff has resulted in the assignment of David Lewis as manager of the Pittsburgh area, extending from Erie, Pa., to Rochester, N.Y. Lewis was formerly district manager in the Pittsburgh area for *Mechanization*. Rodney W. Cramer, formerly in charge of the combined operations, will concentrate exclusively on Ohio as Cleveland regional manager.

New regional manager for the Chicago region is William Graham who has had seven years experience selling advertising space for *Building Construction Illustrated* and *American Metal Market*. He takes over from Donald G. Walter, who is now regional manager in Detroit.

a name...
a company...
to remember!

CLEVELAND ALLOY CASTINGS INC.



You know what you need in heat and corrosion resistant alloys.

Let our engineering staff consult with you . . . we can save you money . . . save you time . . . because quality and know how tempered with the best possible service is the reason Cleveland Alloy Castings, Inc. is reliable . . . is qualified and can meet your specifications for heat and corrosion resistant alloy castings.

Before final decision . . . let Cleveland Alloy make a bid on your next requirements.

Phone collect . . .
Berea 4-3222 or write to . . .

Cleveland Alloy Castings, Inc.
20303 FIRST AVENUE • BEREA, OHIO
Circle 448 on Page 48-B

To get the most out of barrel finishing

ask Oakite

OVER 50 YEARS CLEANING EXPERIENCE • OVER 250 SERVICE MEN • OVER 160 MATERIALS

Barrel finishing cuts unit-cost of deburring from 15¢ to 1¢! How much could it save you?

In one midwest plant, total cost of deburring 20,000 complex aircraft parts by barrel method came to less than $200. This compares with a former cost of $3,000 by hand methods.

This startling reduction in cost is the result of handling hundreds of pieces at a time, instead of grinding each one separately . . . and the result, too, of using the right compound to help the media and barrel do their work.

It's in selecting and supplying the right compound that Oakite helps you get the most out of barrel finishing. Oakite compounds include alkaline and acidic types . . . for steel, brass, zinc die castings, aluminum or alloy parts.

Ask your local Oakite man about barrel finishing, or write for free booklet on barrel finishing to Oakite Products, Inc., 28A Rector Street, New York 6, N. Y.

it PAYS to ask Oakite

OAKITE

over 50 Est. 1909 SCIENCE years' leadership in industrial cleaning

Circle 449 on Page 48-B

Personals . . .

Eugene O'Connor – from investigation metallurgist at Solar Aircraft Corp., Des Moines, Iowa, to manufacturing research engineer at Lockheed Missile and Space Div. in Sunnyvale, Calif.

John G. Ziemann – from assistant chief metallurgist to chief metallurgist, Metals Div., Kelsey-Hayes Co., New Hartford, N. Y.

George Hemmeter – from manager, metallurgical research and development, at the Ft. Wayne (Ind.) Laboratory of General Electric Co. to manager of manufacturing, specialty alloys section, metallurgical products department for G. E. in Detroit.

Garry L. Greenberg – from research metallurgist at International Harvester to project metallurgist at Bell and Howell in Lincolnwood, Ill.

John F. Fischer – from assistant supervisor at Hughes Tool Co. in Houston, Tex., to chief metallurgist for Smith Tool Co., located in Compton, Calif.

Ralph H. Hughes – from operations manager of Security Engineering Div.'s Whittier, Calif., plant to vice-president, manufacturing at the main Dallas, Tex., plant.

Robert F. Lutz – from chief metallurgist, Rockwell Standard Corp., Transmission and Axle Div. in Newark, Ohio, to factory manager of Bosworth Steel Treating Corp., Detroit.

R. H. (Doc) Watson – from operating engineer with the Vancouver, Wash., Works of Aluminum Co. of America to Alcoa's Pittsburgh offices in the salary administration department.

Gerald H. Tenney – awarded the Scroll of Appreciation and Gold Medal of the Third International Conference on Nondestructive Testing held in Tokyo in March of this year for his contribution to the advancement of research and the furtherance of international cooperation in the field of nondestructive testing. Dr. Tenney is group leader of the nondestructive testing group at Los Alamos Scientific Laboratory, Los Alamos, N. M.

Modern welding processes like these demand a modern power supply!

*** TIG** (Tungsten Inert Gas) *** MIG** (Metallic Inert Gas)
*** Short Arc * Submerged Arc**
*** Magnetic Flux**

Glenn Constant Voltage Power Supply with Stepless Vernier Slope Control

Never underestimate the importance of the power supply to the proper operation of today's improved welding processes.

Weld quality, appearance, speed and economy all depend on matching arc characteristics to the requirements of the process and the material. If your power supply can't produce the required characteristics, you're sure to lose some or all of the performance you want.

Glenn Pacific, working closely with major welding process development engineers, has kept pace with process requirements. For example, GLENN constant voltage power supplies with linear slope control have solved major problems in MIG and Short Arc welding on aluminum and ferrous alloys, and many exotic "space age" metals.

Get the facts *now* about GLENN Power Supplies matched to your welding needs—you'll be hours and dollars ahead! For details, please address Dept. 136.

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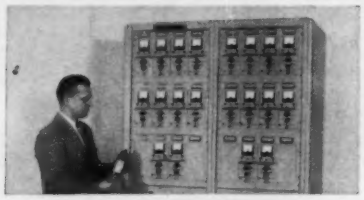
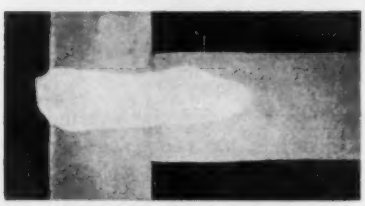
Circle 450 on Page 48-B

NEWS from the NRC Vacuum MICRONICLE*



ALPHATRON® GAUGES SPEED ANALYSIS OF HYPERSONIC DATA

The tried and true Alphatron® ionization vacuum gauge now has a new job — speeding the results of hypersonic wind tunnel tests. Multi-point pressures are measured almost instantaneously and fed into high speed computers. Accuracy is better than ±2% in the range of 1-30 mm. Hg. The 20 channel system pictured above is a modification of the standard Alphatron® gauge, which provides continuous and accurate measurements of pressure from 1000-0.0001 mm. Hg.



ELECTRONS WELD THE UNWELDABLE!

Welding problems posed by reactive metals, dissimilar materials, heat sensitivity, or unusual geometry are now solved with electron beam welders. Freedom from contamination, porosity, and distortion; spot size controllable from 10 mils to 3 inches; depth/width ratios of 4/1; and precision welding at the bottom of 1/16 inch wide slot are some of the advantages of the new process. And equipment prices are surprisingly low.

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Personals . . .

J. E. Jenkins – resigned as chief, metallurgy branch, Lewis Research Center, National Aeronautics and Space Administration, to take on a new job with the British Machine & Tool Co. in Forrestville, Conn.

David J. Pezdirtz – from metallurgical research engineer, Battelle Memorial Institute, Columbus, Ohio, to chief metallurgist and manager of metal abrasive quality control, Globe Steel Abrasive Co., Mansfield, Ohio.

Norman Naimy – now sales engineer in the Michigan area for the National Alloy Div. of Blaw-Knox.

Donald B. Fulton – from vice-president, manufacturing, to vice-president and general manager of the Northern Malleable Iron Co., St. Paul, Minn. He was also named a director of the company.

Richard H. Harrington – named to head the Watervliet Arsenal physical science laboratory's research and engineering division; formerly, assistant professor of mechanical engineering at the University of Massachusetts.

Gordon M. Reid – from assistant foundry metallurgist with Crouse Hinds Co., Syracuse, N. Y., to sales engineer, Debevoise-Anderson Co., New York.

Elmer E. Richardson – from plant superintendent to manager of the Bridgeport, Conn., plant of Heppenstall Co.

R. W. Ramage – from assistant manager to manager, eastern sales, Bliss & Laughlin, Inc., Buffalo, N. Y.

George A. Pease – transferred from the research laboratory of International Nickel Co. to the Huntington (W.Va.) Works to head the new welding section at the Works laboratory.

Paul C. Huang – from maintenance metallurgist, Gary Sheet and Tin Mill, U. S. Steel Corp., to foundry metallurgist, Johnston (Pa.) Works of U. S. Steel.

Jerry C. La Plante – now assistant chief metallurgist, Alloys Unlimited, Inc., in L. I., N. Y.

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ILLINOIS
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Chicago Malleable Castings Co., Chicago 43
Moline Malleable Iron Co., St. Charles
National Mall. and Steel Castings Co., Cicero 50
Peoria Malleable Castings Co., Peoria 1
Wagner Castings Company, Decatur

INDIANA
Albion Malleable Iron Company, Muncie Division, Muncie
Link-Belt Company, Indianapolis 6
National Mall. & Steel Castings Co., Indianapolis 22

IOWA
Iowa Malleable Iron Co., Fairfield

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MINNESOTA
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NEW HAMPSHIRE
Laconia Malleable Iron Co., Laconia

NEW YORK
Acme Steel & Mall. Iron Works, Buffalo 7
Frazer & Jones Company Division Eastern Malleable Iron Co., Solvay
Oriskany Malleable Iron Co., Inc., Oriskany
Westmoreland Mall. Iron Co., Westmoreland

OHIO
American Malleable Castings Co., Marion
Central Fdry. Div., Gen. Motors, Defiance
Dayton Mall. Iron Co., Ironton Div., Ironton
Dayton Mall. Iron Co., Ohio Mall. Div., Columbus 16
Maumee Malleable Castings Co., Toledo 5
National Mall. and Steel Castings Co., Cleveland 6

PENNSYLVANIA
Buck Iron Company, Inc., Philadelphia 22
Erie Malleable Iron Co., Erie
Lancaster Malleable Castings Co., Lancaster
Lehigh Foundries Company, Easton
Meadville Malleable Iron Co., Meadville
Pennsylvania Malleable Iron Corp., Lancaster

TEXAS
Texas Foundries, Inc., Lufkin

WEST VIRGINIA
West Virginia Mall. Iron Co., Point Pleasant

WISCONSIN
Belle City Malleable Iron Co., Racine
Chain Belt Company, Milwaukee 1
Federal Malleable Company, Inc., West Allis 14
Kirsh Foundry Inc., Beaver Dam
Lakeside Malleable Castings Co., Racine
Milwaukee Malleable & Grey Iron Works, Milwaukee 46

These companies are members of the Malleable Castings Council

Circle 492 on Page 48-B

Photo-elastic stress patterns produced by models photographed with polarized light are one of the modern analytic tools available for ever-increasing perfection of Malleable iron castings.

For Greatest Strength Per Dollar... Use Malleable

To improve quality and cut costs, you'll find nothing better than Malleable iron castings. They provide more strength per dollar than any other metal, ferrous or non-ferrous! With Malleable you also get proven toughness, uniform quality and unsurpassed machinability.

See for yourself how much Malleable castings will improve your products and cut your costs. Send drawings or an outline of your requirements to a nearby Malleable castings producer who displays this symbol—

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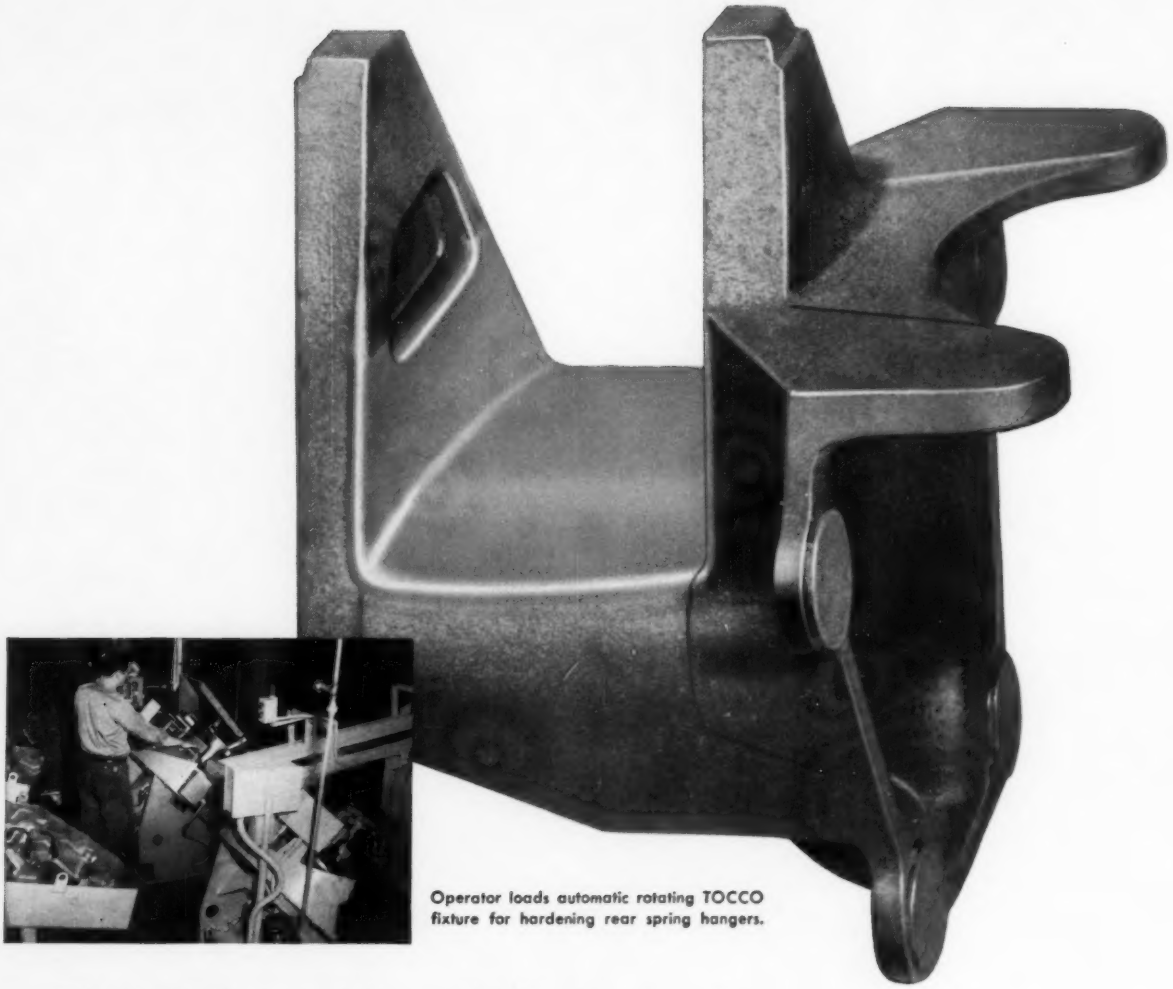
CASTINGS COUNCIL

For detailed information on "Strength Characteristics of Malleable Iron Castings", contact any of the progressive companies listed on the opposite page, or Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.



Operator loads automatic rotating TOCCO fixture for hardening rear spring hangers.

The job they said "couldn't be done"

now being hardened—1 every minute

with TOCCO* Induction Heating

This unusually shaped part is a rear spring hanger used in the spring suspension system of a major truck manufacturer. The hardness pattern covers the "flat" section, which actually isn't flat but blends two widely varying radii, and the sides or "ears" a portion of which must be hardened to the same depth—.060" to .090". Nine of these irregularly shaped castings are loaded in a rotating fixture and scanned progressively by a TOCCO inductor block at the rate of one per minute. An air gap of .060" is maintained between the inductor and the part—quite a tricky achievement since the spring hangers are unmachined castings with normal foundry tolerances of ±.045".

This job is typical of many where TOCCO engineers have worked out a satisfactory and reliable production setup for a supposedly impossible heating job. If you have a difficult heating job—hardening, brazing, soldering or heating for forming or forging it will pay you to consult TOCCO—without obligation, of course.

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The Ohio Crankshaft Co. • Dept. R-7, Cleveland 5, Ohio

Please send copy of "Typical Results of TOCCO Induction Hardening and Heat Treating"

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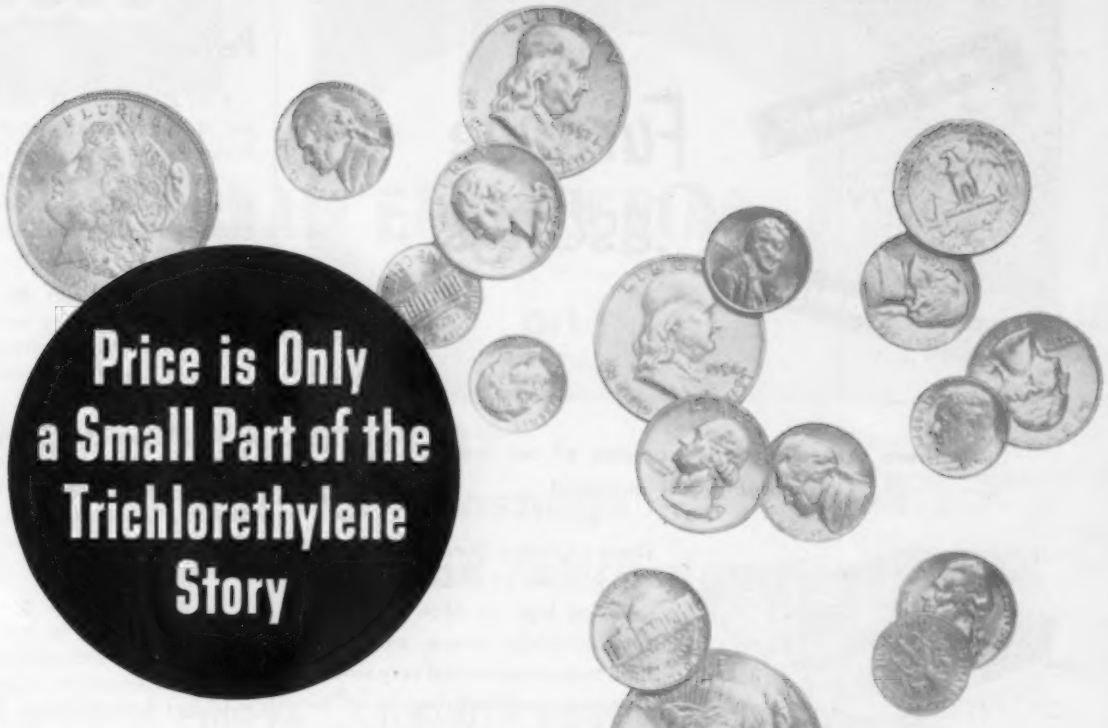
Circle 491 on Page 48-B



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The Efficiency of Your Cleaning Operation Is of Much More Importance

Detrex Perm-a-clor is universally recognized as a premium grade solvent, selling at regular price. *There is none better.*

Buying from questionable sources or the use of unproved solvent can result in an inferior finishing operation which actually costs money instead of saving it.

One sure way to save *real* money on trichlorethylene is through an expert engineering analysis of the overall degreasing operation—your equipment, your methods, the proper instruction of your people.

Detrex engineers have been making such operational studies for more than 30 years. In many, many instances they have set up a program that has reduced solvent consumption by 15% to 25%. They would like to help you.

Depend on DETREX for Every Metal Cleaning and Processing Need

- PERM-A-CLOR NA (Trichlorethylene)
- Solvent Degreasers
- Ultrasonic Equipment
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Write for Dr. C. E. Kircher's informative article: "How to Get the Most Out of Solvent Degreasing".

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World's Largest Exclusive Producer of Cleaning Chemicals and Equipment

35% NICKEL

DURALOY

15% CHROMIUM

Furnace Castings

Here are two good examples of our work in high-nickel castings!

These are in the Duraloy HT group calling for Ni 33.37 percent. We've gone as high as 68% nickel on some castings where extremely high temperatures and very severe corrosive conditions had to be resisted. The important factor concerning castings for exceptionally high temperatures is that they must retain their structural form under load.

Knowing just how much nickel to put in and how much chromium and other alloying elements depends to a large extent on experience . . . and it is experience that we can offer you for the castings you need. We've been producing static castings since 1922 and centrifugal castings since 1933, being among the pioneer founders in each class.

If you would care to have our metallurgist study your casting problem, we shall be glad to have you call upon us for the service.

Our New General Catalog is yours for the asking.

HIGH ALLOY CASTINGS

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EASTERN OFFICE: 12 East 41st Street, New York 17, N. Y.

CHICAGO OFFICE: 332 South Michigan Avenue

DETROIT OFFICE: 23906 Woodward Avenue, Pleasant Ridge, Mich.

Circle 460 on Page 48-B

Personals . . .

Carl H. Samans ⊕, national trustee of A.S.M. and member of the Metal Progress Advisory Committee —now director of engineering metals division, research and development department, Standard Oil Co. of Indiana, Whiting, Ind.

William B. Wallis ⊕ – retained on a full-time basis by Strategic Materials Corp. as a consulting engineer to assist in the promotion of the Strategic-Udy processes.

Louis Moses ⊕ – retired as mill engineer in the construction engineering department of Bethlehem Steel Co., Bethlehem, Pa., after 60 years of service with the company and its predecessors.

L. McD. Schetky ⊕ – formerly chief metallurgist in Massachusetts Institute of Technology's instrumentation laboratory, currently vice-president and technical director of the Alloyd Corp., Cambridge, Mass.

Findley Griffiths ⊕ – from executive vice-president, commercial, to president of Acme Steel Co., located in Chicago.

F. D. Delve ⊕ – from research engineer in the Graham Laboratory of Jones & Laughlin Steel Corp. to supervising metallurgist in the Steel Works Div., in the metallurgical department at J&L's Pittsburgh Works.

Robert F. Poynton ⊕ – to sales and service representative in the New England area for Neilson Chemical Co., Detroit.

Bruce O. Young ⊕ – from market development coordinator with the alloy and carbon specialties division, to product manager, alloy and carbon specialties, with Crucible Steel Co. of America.

Owen J. Williams, Jr. ⊕ – from chief metallurgist, Cincinnati Shaper Co., to chief metallurgist, Metal Treating, Inc., Cincinnati, Ohio.

Jack B. Freeman ⊕ – appointed eastern district sales manager of MRC Mfg. Corp., Yonkers, N. Y.

S. L. Jackson ⊕ – from assistant manager to manager of the eastern sales region of Union Carbide Metals Co., a division of Union Carbide Corp.

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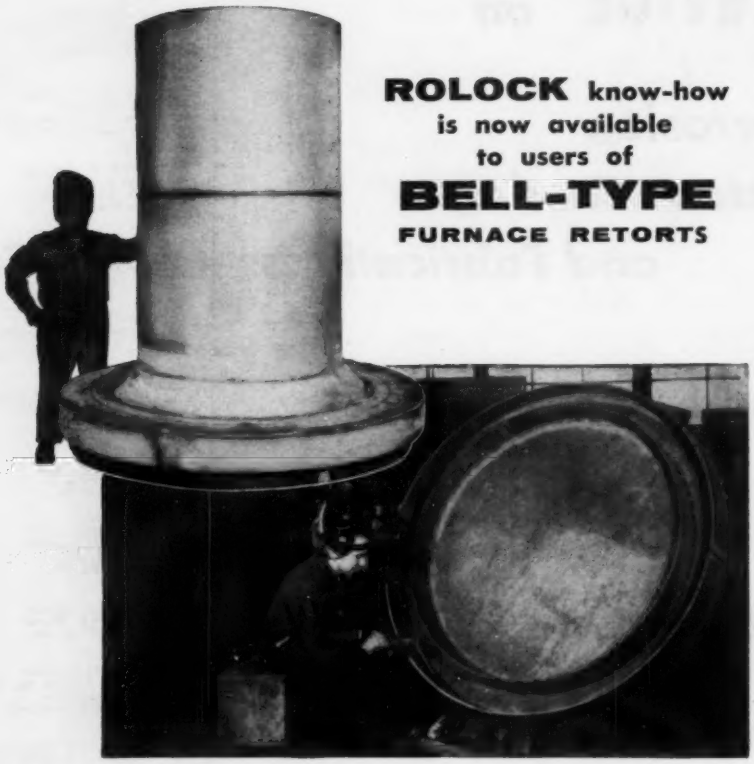

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Personals . . .

Joseph E. Burke, manager of the ceramic studies section at the General Electric Research Laboratory in Schenectady, N.Y. – elected chairman of the basic science division, American Ceramic Society.

John H. Tinnemeyer, Jr. – from assistant superintendent to superintendent of blast furnaces at the Neville Island plant of Pittsburgh Coke & Chemical Co.

Dusan M. Pavlonic – on a temporary assignment as Westinghouse resident engineering representative at Siemens companies' headquarters in Erlangen, West Germany.

Verne C. Kennedy, Jr. – currently executive director of the University of Oklahoma Research Institute in Norman, Okla. In addition to his duties at the Institute, he is an assistant professor in the department of metallurgical engineering.

George F. Hodgson – now director of research of the Doehler-Jarvis Div. of National Lead Co. in the research and engineering department at Toledo, Ohio.

Peter Leckie-Ewing – now manager of technical services at Latrobe Steel Co., Latrobe, Pa.

Frank E. Harness – from chief metallurgist, Gardner-Denver Co., Quincy, Ill., to chief metallurgist at the Ductile Iron Foundry, Inc., Stratford, Conn.

Jerome B. Cohen – at present assistant professor in the department of materials science of the Technological Institute of Northwestern University.

A. Eisenlohr – from development engineer at the Flight Propulsion Laboratory Dept. of General Electric Co. in Evendale, Ohio, to spraying manager, Thermal Dynamics Corp., Lebanon, N. H.

James E. Battles, senior metallurgy student at the University of Alabama – awarded the first Vernon W. Jones Scholarship. The award was instituted in honor of a former chairman of the National Open-hearth Steel Committee of the Iron and Steel Div. of the Metallurgical Society, A.I.M.E.

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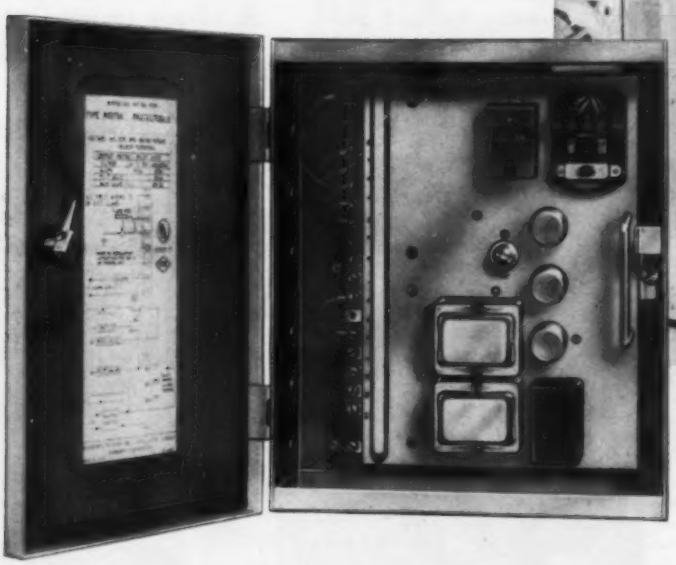

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Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Welding Titanium and Its Alloys

Digest of "The Welding of Titanium and Titanium Alloys", by G. E. Faulkner and C. B. Voldrich, DMIC Report 122, Dec. 31, 1959, Battelle Memorial Institute, Columbus, Ohio.

TWO CHARACTERISTICS of titanium (and its alloys) make it one of the most difficult metals to weld. First, when heated to welding temperatures, it is highly reactive with air and most elements and compounds. Second, small amounts of impurities, notably oxygen, hydrogen, nitrogen and carbon, have a pronounced detrimental effect on ductility and toughness of the welds.

Particularly difficult is the welding of titanium to other metals such as steel, nickel and copper alloys. Brittle intermetallic compounds form in the fusion zones. With columbium, molybdenum, tantalum and zirconium, brittle intermetallics are not a problem, but low ductility of welds may result because of high solid solubility. With care, the metal can be welded by the gas-shielded metal-arc process and by seam, spot, flash and pressure welding.

Clean Surfaces – One of the important steps in welding titanium is surface preparation. Metal covered with a light oxide seal should be pickled in an acid solution. A solution containing 2 to 4% HF and 30 to 40% HNO_3 is suggested.

Thick scale (formed above 1100° F.) is best removed in molten salt baths of NaOH plus oxidizers, or hydrogen added to form sodium hydride. Excessive hydrogen pickup by the metal is a problem here. Vapor and grit blasting have also been used to remove scale. Both of these latter treatments should be followed with an acid pickle.

Welding Methods – It is important during inert-gas-shielded metal-arc welding (tungsten arc or consumable electrode) to shield the weld root and face while the metal is above 1200° F. Otherwise, these areas will be contaminated by rapid diffusion of oxygen, nitrogen and

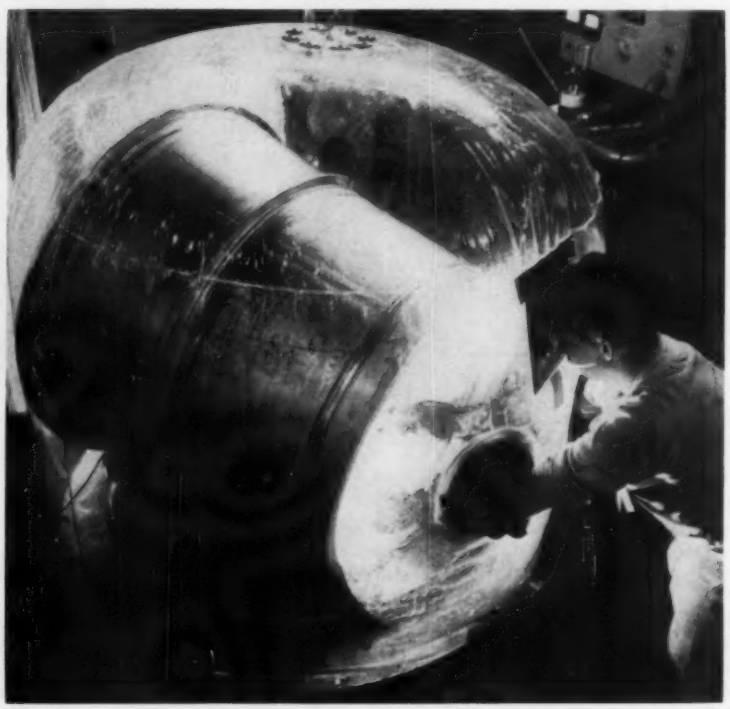

Fig. 1 – Collapsible Plastic Chamber for Welding Titanium Is Collapsed Several Times and Filled With Inert Gas. (Courtesy Pratt and Whitney Aircraft)

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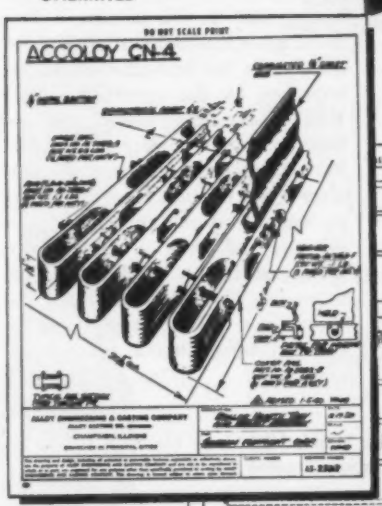

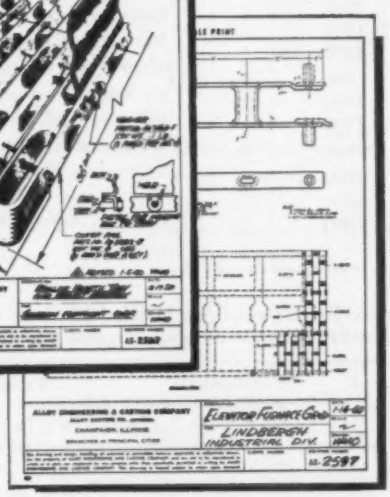

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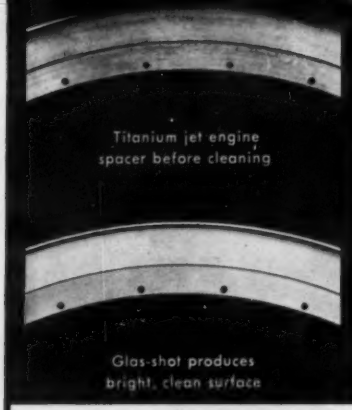

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Welding Titanium . . .

water vapor into the molten weld puddle. Surface contamination also occurs in areas which are above 1200° F. In welding titanium in open air, it is advisable to provide gas nozzles which are larger than those used for other metals. For tungsten arc welding, ¾-in. diameter nozzles are preferred; for consumable electrode welding, 1-in. diameter nozzles should be used.

The weld root should be protected by uniform gas flow channeled through a backing bar in some manner. Welding fixtures also affect weld quality. Hold-down bars, for example, act as baffles to contain the gas in the weld zone. They also provide a chilling effect in addition to holding the parts in alignment.

When the complexity of a part makes open-air welding impractical, the part may be welded in a chamber filled with inert gas. Both rigid and collapsible plastic chambers (Fig. 1) are used.

Joint designs for titanium are similar to those for other metals. Fitup is particularly important because molten titanium is highly fluid.

Sheets up to 0.1 in. are usually welded by the tungsten arc process (using straight-polarity direct-current); above 0.1 in. a consumable electrode (reverse-polarity direct-current) is recommended. Mixtures of argon and helium for shielding weld faces have come into use. Argon alone provides adequate shielding at lower flow rates, but helium permits deeper penetration and higher welding speeds.

Spot and seam welding of titanium demand accurate control of welding current, time, and electrode force. Shielding is not necessary. Variation in strength, diameter and penetration of spot welds is pronounced, especially with changes in welding current and time. One rule of thumb in establishing welding conditions is to use those recommended for stainless steels as a start.

Flash welds have been produced which consistently possess mechanical properties equal to those of the base metal. In this process, molten metal is not retained in the joint, and ductility in the heat-affected zone is improved by the upsetting action. When flash welding hollow cross sections, inert-gas shielding is advisable. For solid parts, shielding is not necessary, but is often used. Flashing current, speed and time, and upset pressure and distance are the most influential factors in flash welding titanium. Generally, fast speed and short times with upset pressures between 7000 to 20,000 psi are recommended. *(Cont'd on p. 158)*

Table I – Stress-Relieving Treatments for Titanium

Alloy	Temp.	Time
Commercially pure titanium	800° F.	8 hr.
	900	¾
	1000	½
5 Al, 2.5 Sn	900	20
	1000	6
	1100	2
	1200	1
6 Al, 4 V, annealed	900	20
	1000	2
	1100	1
6 Al, 4 V, solution treated	900	15
	1000	4
6 Al, 4 V, solution treated and aged	900	15
	1000	5

Table II – Properties of Arc Welded 13 V, 11 Cr, 3 Al Titanium Sheet in Solution Treated Condition

Postweld Treatment	Strength		Elongation	
	Tensile	Yield	in 2 In.	in ½ In.
As welded	131,000 psi.	127,000 psi.	24%	—
As welded	136,000	129,000	5 to 18	12 to 18%
Aged (*a*)	156,000	—	0	0
Aged (*b*)	189,000	176,000	—	2
Low-high (*c*)	174,000	165,000	2	8
Low-high (*d*)	186,000	169,000	—	4

(*a*) 900° F., 50 hr., air cool.
(*b*) 900° F., 72 hr., air cool.
(*c*) 900° F., 60 hr., air cool; 1100° F., 15 min., air cool.
(*d*) 900° F., 72 hr., air cool; 1050° F., 10 min., air cool.

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☛ *Among test samples prepared from air-melted wire, 18 out of 32 failed at the weld.*]

☛ *Among similar samples prepared from the vacuum-melted wire of the same grade, only two out of 32 bars failed at the weld.*]

[*Different alloys of Cannon-Muskegon vacuum-melted welding wire are available in sizes from 1/32" to 1/8", in 36" cut lengths, or in 10 or 25-lb. spools packed in airtight Argon-filled steel containers.*

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Welding Titanium . . .

Greater application of pressure welding for welding titanium can be expected in the future. This is especially true for joining the high-strength heat treatable alloys (in these, arc welds possess low ductility). Conventional gas-pressure welding equipment is satisfactory. Closed-joint pressure welding is used, and upset pressure (2500 psi.) is applied throughout the heating cycle. The parts to be joined should be machined so that they are in intimate contact in the machine. As in flash welding, solid pieces do not require inert-gas shielding. With hollow parts, however, the weld root should be protected.

Inspection – Besides the usual nondestructive methods for inspecting welds, visual inspection is effective in determining whether adequate shielding was provided during welding. Experience has shown that welds with either dull white, gray or yellow scale are excessively contaminated. With improved shielding, the surface takes on a bright metallic blue or gold appearance; this indicates that there is surface contamination, but that the underlying weld metal is sound. Nearly perfect shielding is indicated if the surface has the appearance of newly polished silver.

Stress-Relieving – Complex welded assemblies are commonly stress-relieved when completed, and sometimes during fabrication. Representative treatments are shown in Table I. Stress-relief should be followed by cleaning as previously described. Where sizing is required, it is carried out at those temperatures recommended for stress-relieving.

Properties – Not all alloys respond to the various welding methods in the same manner. Of the alpha alloys, only commercially pure titanium and the 5 Al, 2.5 Sn titanium alloy have been used extensively for welding operations. Joints are strong and ductile.

Most of the arc welds produced in alpha-beta alloys are too brittle. Attempts to improve weld ductility by heat treatment have demonstrated that annealing treatments which are best for this purpose are impractical because they result in low base-metal and joint strength. The only alpha-

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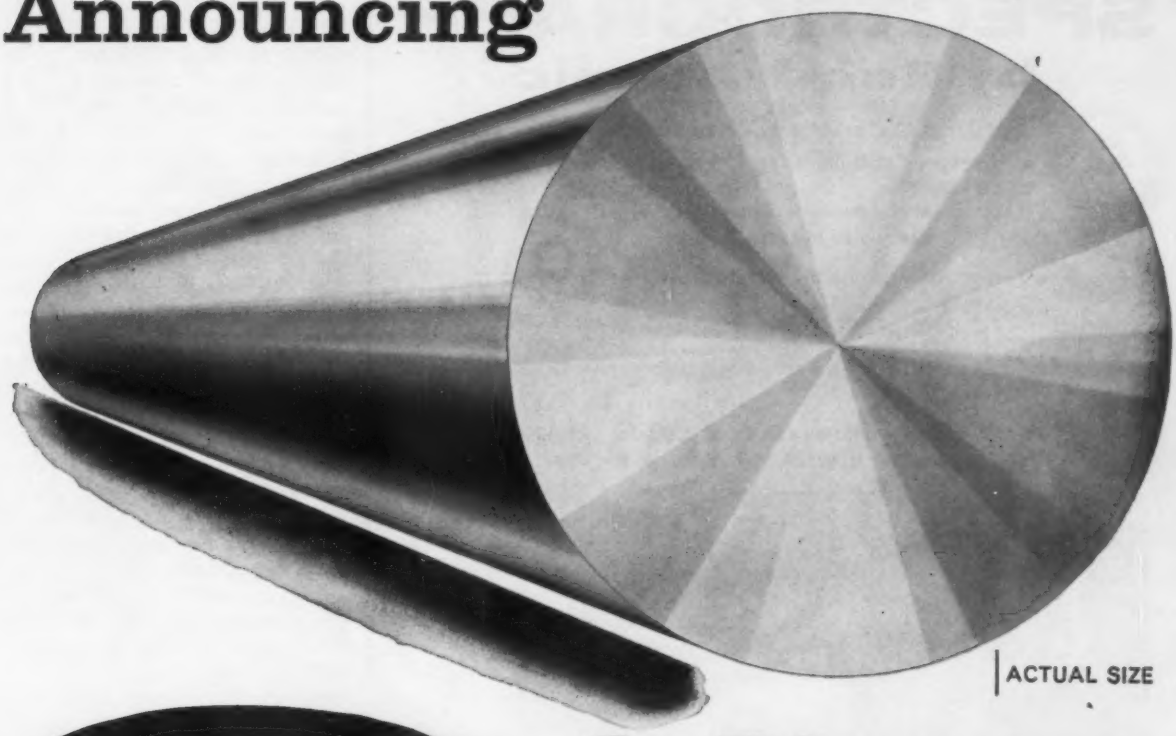

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Circle 469 on Page 48-B

Welding Titanium . . .

beta alloy used extensively in arc welding is 6 Al, 4 V titanium. This alloy is employed in the annealed and heat treated conditions with welded joints being stress-relieved, in the as-welded condition, or heat treated.

Only one beta alloy (13 V, 11 Cr, 3 Al) is commercially available. Inert-gas metal-arc welding produces ductile welds of low strength. Studies aimed at improving strength without impairing ductility have resulted in a promising treatment in which joints are aged at 900° F. for long periods (60 to 72 hr.) and then heated to 1050 to 1100° F. for a few minutes (10 to 15 min.). This is known as a low-high treatment (Table II).

The properties of spot welded joints in titanium and many of its alloys are satisfactory for service. As long as the welding process is properly controlled and the sheets are clean, welds of high tension-shear strengths are obtained regularly. Unfortunately, low cross-tension strengths are also common to spot welds. Good fitup during fabrication (along with rivets placed at the ends of spot welded joints to prevent peeling) is suggested.

Thermal stability is a problem in titanium spot welds because of their susceptibility to transformation at elevated temperature. The result is embrittlement. Tests indicate that spot welds in 6 Al, 4 V titanium possess good stability while that of spot welds in 16 V, 2.5 Al is poor. Principally because of their long availability and extensive background data, the following are the most widely used titanium alloys for spot welding applications: commercially pure titanium; 5 Al, 2.5 Sn; 6 Al, 4 V; and 8 Mn titanium alloy.

Seam welds are generally of good quality. In tests, failure usually occurs in the base metal. Flash welds also usually fail away from the weld center line. Information on pressure welding is limted to data on one alloy, 6 Al, 4 V. In some tests, the weld metal has exhibited lower strength than the base metal, but in general the weld strength is equivalent to or exceeds that of the base metal. Very few pressure welds fail along the weld plane.

R. G. D.

(More digests on p. 168)

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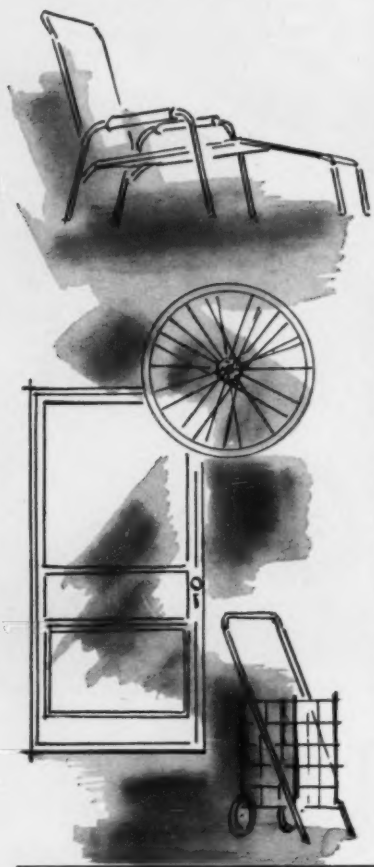


Here's a fast, easy way to practically double corrosion protection on your products. Simply follow the Iridite process with an application of Irilac. You give parts extra protection from corrosive conditions, added abrasion resistance, longer shelf or storage life, protection from finger marking and increased beauty for a more attractive appearance and faster sales.

ON ALUMINUM—An Iridite-Irilac finish provides long life under many service conditions. Iridite colors range from natural aluminum to golden yellow. Additional dyes give other color ranges.

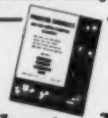
ON MAGNESIUM—Irilac over Iridite 15 increases protection, resists damage from handling or abrasion. Color range—light to dark brown.

ON ZINC—Iridite plus Irilac gives longer product life, brighter appearance. Color range—clear Iridite to olive drab, plus colored dyes.

IRIDITE—chromate conversion coatings for non-ferrous metals applied by dip, brush or spray, at room temperatures manually or with automatic equipment. Provides corrosion resistance, a base for paint or decorative appearance. Forms a thin film integral with the metal. Cannot chip, flake or peel. No special equipment, exhaust systems or specially trained personnel required.

IRILAC—Clear protective coatings for all metals. Safe and easy to handle as water. Apply by dip or brush. No exhaust or special fire prevention equipment required. Adds protection and abrasion resistance to base metals, plated parts or parts treated with electrolytic or chemical post treatments without chemical change.

For complete technical information on IRIDITE or IRILAC coatings, write for FREE TECHNICAL MANUAL. Or, see your Allied Engineer. He's listed under "Plating Supplies" in the yellow pages.



Allied Research Products, Inc.

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West Coast Licensee for Process Chemicals: L. H. Butcher Co.
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IRIDITE® Chromates | IRILAC® Coatings | ISOBRITE® Brighteners | ARP® Supplies | WAGNER Equipment

Circle 471 on Page 48-S

Welding Electrodes . . .

(Continued from page 100)

ointment: There appears to be a tendency to lose notch-toughness after long-time aging at 1200 and even more at 1350° F.

In order to conduct a more comprehensive investigation of the room and elevated-temperature properties of the high-nitrogen extra-low-carbon 18-8 welds, wire from four experimental heats is being obtained for more extensive tests.

Practical Significance of the Over-All Program

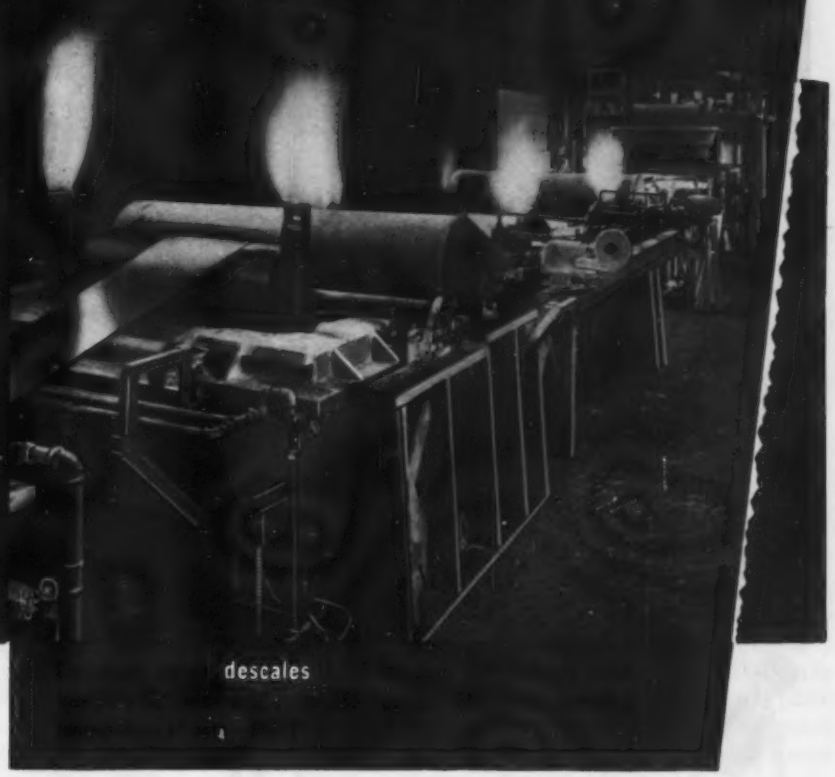
The results of the years of testing under review have confirmed the idea that cracking of weld metal in stainless steel is clearly an inverse function of ferrite content. It was also confirmed that, at least in columbium-bearing alloys, the ferrite transforms to brittle sigma during exposure to elevated temperatures. When ferrite is eliminated, cracking becomes a severe problem unless carbon or manganese is increased substantially. The Composition C alloy, which is fully austenitic by virtue of high (0.12%) carbon, and Composition H, based on high (5%) manganese, were both proven to be suitable for production welding of austenitic stainless steels and were free from the ferrite-to-sigma transformation.

On the basis of stress-rupture tests, all three electrode compositions, H, C, and A, appear to be suitable to join Type 347 stainless, since they are stronger than the base metal, Compositions 16-8-2, H, and C possess superior tensile ductility to the partially ferrite Type 347 weld metal (Composition A) in the 1500 to 2000° F. range.

Standardized corrosion tests have shown that all three columbium-bearing welds possess acceptably low corrosion rates in the as-welded and annealed conditions. The 16-8-2 weld metal is not suitable in applications which must resist intergranular corrosion. In general, the Type 308 L weld deposit (Composition F) has the best corrosion resistance of the compositions studied.

For applications where impact strength at very low temperatures is required in a columbium-bearing weld, the partially ferritic standard

DREVER Salt Bath DESCALING



The above 35′-0″ long Drever Continuous Descaling Bath will descale 18,700 lbs/hour when strip enters bath at bath temperature. Entering strip temperature is controlled by regulation of quenching temperature after strip is discharged from a catenary annealing furnace.

Drever descaling baths are heated by gas-fired immersion tubes with proportioning automatic temperature control.

Other baths are supplied for continuous or batch operation for strip, plate, wire, tubing and other ferrous or non-ferrous products.

Write for full information...

DREVER COMPANY

Circle 472 on Page 48-B

escaped helium costs you money

You can save $20,000 a year with an LM Recovery-Purification System if you are using 100 cylinders of helium per month.

Typical applications include...

- **Inert gas welding**
- **Heat treating or melting sensitive materials**
- **Growing semiconductor single crystals**
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If your problem is...

- **Heat Transfer at High Temperatures, or**
- **Circulation of a Liquid Metal . . .**

let an LM engineer help you solve it. LIQUID METALS, Inc. offers complete, packaged Heat Transfer Systems and Test Loops. Individual components are also available separately.

Design excellence is characteristic of all LM products. Typical is LM's line of zero-leakage, high-efficiency ELECTRODYNAMIC PUMPS — featuring . . .

- **standard pump cells for continuous operation to 1650°F.**
- **special pump cells for higher temps.**
- **pressures to 500 psi.**
- **capacities to 20,000 gpm.**
- **simple manual or automatic control of pressure and flow-rate**
- **reversible pumping direction**

Phone an LM Applications Engineer, at

LIQUID METALS, INC. Box 2667, Westford, Mass., MYrtle 2-8032

Circle 473 on Page 49-B

Welding Electrodes...

Type 347 weld would be the first choice. However, the noncolumbium 308 L alloy has the maximum low-temperature toughness.

The probable field of application of each of the electrodes seems to be as follows:

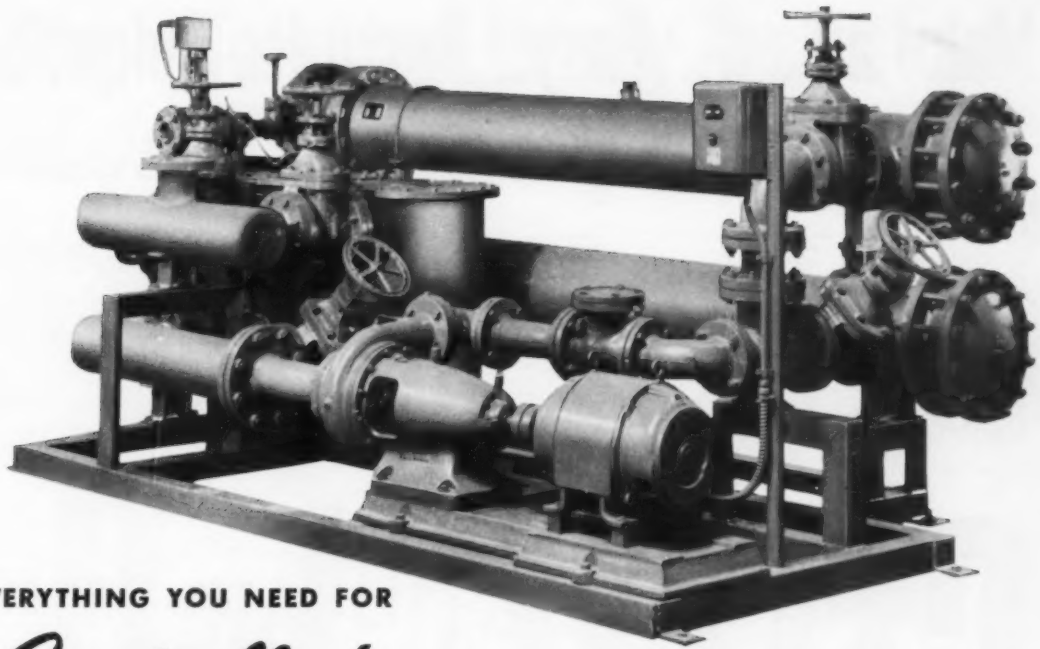
Electrode Composition A is representative of present commercial Type 347 electrodes, since its welds will contain 7% ferrite in the as-welded condition. It is the most suitable of the columbium-bearing varieties for fabricating equipment; joints should be free from cracks and fissures even though welded under restraint. If a columbium-bearing weld metal should be required for low-temperature applications (about −300° F.), Composition A will be suitable if the equipment is heat treated at 1700° F. or higher.

Electrode Composition C – In applications where a fully austenitic metal is essential and high carbon (0.12%) is not considered objectionable for other reasons, such as highly corrosive service, Composition C might well be considered. The high carbon might prove to be an advantage in certain high-temperature applications, since this weld metal has the highest stress-rupture strength of the materials tested.

Electrode Composition F is a noncolumbium extra-low-carbon composition; therefore its properties are difficult to compare with those of the others. One of its chief characteristics is high ductility and toughness even after prolonged exposure to heat. It is especially suitable for applications requiring toughness at ambient or very low (−320° F.) temperatures. Another feature is its outstanding behavior in the standard corrosion tests. The room-temperature strength of Type 308 L weld metal was equal to that of Type 304 L plate, but at 1000 to 1300° F. the weld is weaker.

Electrode Composition H – If a fully austenitic Type 347 weld is desired, this 5% manganese composition will meet the requirements – suitability for production welding, corrosion resistance, and stress-rupture strength at 1000 to 1300° F. More crater cracks may be expected than when using partially ferritic compositions. One good feature is

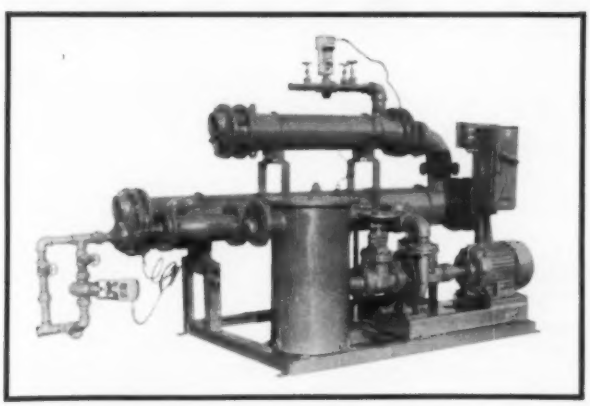
(Continued on p. 166)



EVERYTHING YOU NEED FOR

Controlled QUENCH OIL COOLING

...EITHER COMPONENT PARTS OR SELF-CONTAINED UNITS



BOTH HEATS AND COOLS QUENCH OIL

This typical B&G self-contained unit, as installed in automotive plant, both heats and cools quench oil to definite temperature specifications.

A B&G Self-Contained Oil Quenching System, factory-engineered and factory-assembled, avoids assembly errors, saves labor costs and can easily be moved if plant layout so demands. Your only responsibility, once the unit is delivered, is to place it in position and connect it to the quench tank and water lines. Or, if preferred, component parts can be furnished for assembly on the job.

This system circulates oil from the quench tank, cools and strains it, and pumps it back at a rate which keeps oil at the right temperature throughout the quench period. Every batch is quenched under identical conditions, hence every batch emerges identical in quality.

With a B&G Oil Quenching System, quenching is automatically controlled and results are predictable. You cut losses resulting from excessive rejects and realize a substantial "inside profit."

B&G Quench Tanks

Properly designed to induce maximum turbulence in the quench oil. B&G Quench Tanks are available in standard models or can be built to meet any specific quenching requirement.

Send for this combined Catalog and Simplified Selection Manual for B&G Self-Contained Quench Oil Coolers.

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OIL QUENCHING SYSTEMS

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Circle 474 on Page 48-B

Make a Fast...Easy...Accurate Selection of

and know your size, shape, and grade are

The Allegheny Ludlum Tool Steel

STEELECTOR

- ✔ every type needed for 96% of all tool steel applications
- ✔ easy selection of the proper tool steel based on its individual characteristics
- ✔ stock shipment of grade and size assured at selection time

the Proper Tool Steel for any Application

Available with the A-L Steelector Program

easy answer to an old problem

Starting right now, the common problem of selecting the right tool steel for any job can become a thing of the past. With A-L's new STEELECTOR Program, you can make a *first time choice* of the proper grade for any application . . . and make it FAST, almost at a glance.

eliminates guesswork

The STEELECTOR is ACCURATE, eliminating guesswork, trial runs, and expensive mistakes. And best of all, the STEELECTOR gives you a choice of tool steels that are AVAILABLE . . . in stock, right now! And they'll *stay* available . . . with a new, increased stocking program. STEELECTOR Grades are stocked according to a study of today's needs and will be reviewed periodically to fit changing requirements.

here's how it works

In the new program, a STEELECTOR Card covering each group of steels (Tool Room, Hot Work, and High Speed Grades) will help you select one particular grade as the best for your application. The STEELECTOR presents five basic tool steel properties—Abrasion Resistance—Toughness—Size Stability—Machinability—Red Hardness—as bar graphs, with the length of the bar showing the extent of each property in every STEELECTOR Grade. Find the properties most important to you and, by inspection, pick the grade with the characteristics you need.

availability assured

There is a separate Data Stock List for each STEELECTOR Grade, showing its complete range of warehouse stocks, as well as technical

data and basic application information. So, you can be sure the grade, size, and shape of your choice is in stock.

quality assured

And you can count on Allegheny Ludlum quality in every STEELECTOR Grade. They are selected from the complete line of A-L Tool Steel and made under the rigid quality control standards of all A-L products.

details available

It's all explained in the colorful A-L Tool Steel STEELECTOR Booklet, which includes STEELECTORS for the Tool Room Grades, Hot Work Grades, and High Speed Grades, and explains the Data Stock Lists for every STEELECTOR Grade. Ask your Allegheny Ludlum Sales Representative for your copy, or write: Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa. Address Dept. Ins. 7.

STEELECTOR PROGRAM

ALLEGHENY LUDLUM

Tool Steel warehouse stocks throughout the country

MASSIVE TUNGSTEN AND MOLYBDENUM
New, big-size G-E Refractory Metals

General Electric PS Moly and PS Tungsten are pure metal powders, prepared by hydrogen reduction, cold pressed hydrostatically into basic products and strengthened by sintering in a high temperature hydrogen furnace. You can now get pure PS (Pressed and Sintered) G-E Molybdenum and Tungsten in a variety of large shapes. For example—they're available as forging billets, consumable electrodes for vacuum arc melting, simple preforms, sheet slabs, tubes and other basic forms to fit just about any application for these unique metals in massive form. Plan now on PS metals from General Electric. Write for more information. General Electric Co., Lamp Metals and Components Dept., MP-07, 21800 Tungsten Road, Cleveland 17, Ohio.

FORGE AND ROLL IT—G-E Molybdenum and Tungsten are available in billets up to 8″ O.D. and 27″ long—in slabs up to 7½″ wide and 2″ thick. Minimum densities: Moly 95%, Tungsten 92%.

MACHINE IT—With proper techniques, G-E Molybdenum or Tungsten can be machined easily from billets, tubes and preforms. Density can be varied from 65-95%—±3% tolerance.

MELT IT—For vacuum arc melting, General Electric PS Tungsten and Molybdenum consumable electrodes are available in diameters from 1″ through 6½″. Main features: high purity, density and straightness. Alloys of tungsten and molybdenum are available, too.

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle 475 on Page 48-B

new look
(and greater efficiency)
in Magnetic Particle Flaw Detection Equipment

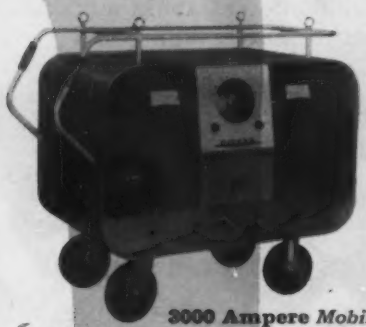
6000 Ampere *Stationary Model*
PICKER FERROSCOPE
for Wet Technics

new outside

- *Clean-lined modern design: easy to clean, easy to keep clean.*
- *Modular principle: units combine to handle parts up to 12 feet long.*
- *Meters and signals function-grouped at eye level.*

new inside

- *New heavy duty silicon full-wave rectifiers run cooler, quieter.*
- *Heat capacity five times greater than MIL Type II specs call for.*
- *Does away with noisy, grime-blowing exhaust fans.*



3000 Ampere *Mobile Model*
PICKER FERROSCOPE
for Wet and Dry Technics

new outside

- *Roll-to-the-job unit: companion design and same finish as big Ferroscope.*
- *Easy to read meters, husky control knobs.*

new inside

- *Same heavy duty cool-running silicon rectifiers as 6000 A. unit.*
- *Heat capacity fivefold greater than required by MIL Type III specs.*
- *Either AC or half-wave DC always on tap for best results with both wet and dry technics.*
- *Stepless current control up to 3000 A.*
- *All operation controllable at machine or by*
- *remote handswitch on long cable.*

For heavy duty inspection schedules, one or the other of these Ferroscopes may be just right for you. Or maybe a smaller Ferroflux or Portaflux portable magnetic particle inspection unit would be adequate to your lighter need. In any case, call in your local Picker representative: he will be glad to advise you about these, or any of the other nondestructive inspection systems Picker offers (they're listed below).

ONE STOP *for all this* ***in non-destructive inspection equipment***

Picker x-ray

PICKER X-RAY CORPORATION
25 South Broadway, White Plains, N. Y.

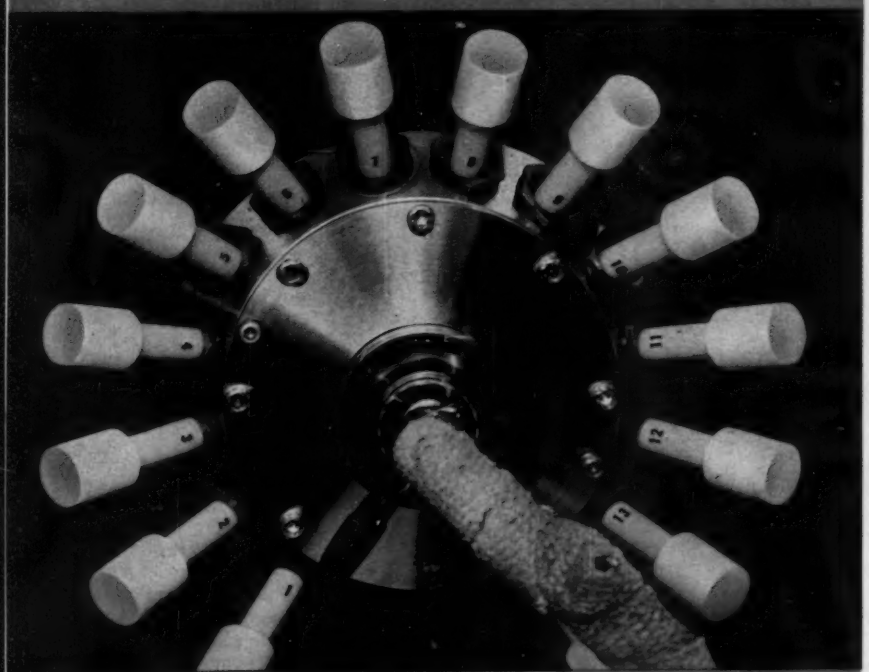
x-radiography	**ANDREX** portable x-ray units-140 KV, 160 KV, 200 KV, 260 KV **PICKER** x-ray units—35 KV Beryllium window, 90 KV, 110KV, 150 KV (stationary and mobile), 270 KV portable
gamma radiography	**PICKER** *Pipeliner*—30 curies, Ir^{192}, *Cyclops*—1500 curies; Co^{60} **TECH/OPS** Iridium^{192} units from 10 to 100 curies; Cobalt^{60} 3 to 100 curies: also Thulium^{170}, Cesium^{137}
fluoroscopy	**PICKER** Image Intensifier and associated equipment
magnetic particle	**PICKER** *Ferroscope* *Ferroflux* *Portaflux* **PIXmag** Ferropowders and pastes
dye penetrant	**PIXchek** Penetrants, Cleaners, Developers, and accessories

Circle 476 on Page 48-E

a mass spectrometer of

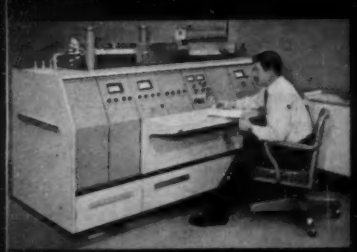
MATCHLESS PERFORMANCE AND VERSATILITY

CEC's new 21-110 Series Mass Spectrometer distinguishes mass differences which no other commercial mass spectrometer can detect. Furthermore, this double-focusing type instrument can be used for qualitative and quantitative analyses of metals and other solids, as well as liquids and gases. The 21-110 will analyze high molecular weight substances and differentiate in any mass range ion species having almost coincidental masses.



HERE'S WHAT YOU CAN EXPECT FROM A 21-110: *Interchangeable ion sources and detectors*—Five modular ion-sources (housing shown above): gas ion source, radio frequency spark, thermal emission, crucible and Knudsen cell. Five modular ion-detectors: photographic plate, electrometer, electron multiplier, isotope ratio detector, and combinations of these — conversions can be made easily by operator.

Highest resolving power — Actual photo-plate record shows three mass spectral lines at m/e 28. The two closest peaks represent ions of CO and N2. The mass difference between them is 0.01123. The 21-110 has resolving power greatly in excess of the one part in 2500 required to resolve these two masses.



For complete information call your nearest CEC sales and service office or write today for Bulletin CEC 1863-X1.

Analytical & Control Division CEC

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Welding Electrodes . . .

its substantially greater tensile ductility in comparison with that of the partially ferritic, Type 347 weld metal between 1500 and 2000° F.

Electrode Composition 16-8-2— For easy fabrication of heavy sections of Type 347 stainless steel, this electrode has performed excellently. However, laboratory tests have indicated that there is a possibility that Type 347 pipe weldments will fail from the inside diameter simply because the 16-8-2 weld possesses much greater capacity for plastic flow than the Type 347 base material at the service temperatures.

Fracture Test . . .

(Continued from page 82)

unnotched surfaces. However, the thin and hard case results in a crystalline-appearing, brittle-behaving frame. It is as though the small (8 × 10-mm.) rectangular section of the standard Charpy V specimen were made a portion of a much larger section which exhibits a cleavage mode of fracture.

Probably, only those tests which exhibit largely crystalline fractures along with the energy values below 5 to 10 ft-lb. for impact tests (or low maximum loads for slow bend tests) will be useful for estimating fracture toughness. This limitation is necessary because the definition of fracture toughness requires that the fracture, once started, be propagated by the release of elastic energy stored during the crack initiation period. The initiation process, on the other hand, must be facilitated. Our test does this by proving that the brittle-behaving layer causes early formation and continuous enlargement of a fast moving crack.

Estimates of fracture toughness, G_{co}, may be made from brittle-boundary impact energy data by dividing the energy expressed in in-lb. by the area (in sq.in.) enclosed by the brittle case.

While these observations were made on a limited number of tests, the application of the "brittle boundary" principle offers much promise. Through this technique, impact values and the fracture appearance

SIGNIFICANT ADVANCES IN BERYLLIUM TECHNOLOGY COME FIRST FROM BRUSH

BERYLLIUM COPPER HELPS BLOW MOLDERS FILL HUGE DEMAND

Cast beryllium copper molds allow shorter molding cycles, give longer, more economical production runs.

Blow molders produced 500,000,000 polyethylene containers last year. This year, the big question seems to be, "Can they puff out enough containers to meet the expected one billion demand?" Molds made of beryllium copper offer part of the answer.

For mold makers, this Brush-alloy is easy to cast to shape without expensive machining, simple to heat treat to hardnesses of Rockwell C44 and tensile strengths to 175,000 psi. For producers of plastics, tough beryllium copper molds last longer, reducing replacement downtime. The alloy's high thermal conductivity aids in shortening mold cycles for more output per machine hour.

Molds for plastics may not be your problem, but Brush may have the answer to some of your tough material requirements. For more information on beryllium, its oxide and its versatile alloys, contact us at 5209 Euclid Avenue or ENdicott 1-5400 in Cleveland, Ohio.

THE BRUSH BERYLLIUM COMPANY

Fracture Test . . .

transition temperature can be obtained from nitrided Charpy tests. Such data can be used with considerable advantage in selecting fracture resistant alloys. The use of brittle specimens can possibly be extended to other steels and perhaps to other metals such as titanium alloys by suitable choice of surface treatment to produce the brittle case.

Western Meeting

Digest of a report on the Assoc. of Iron and Steel Engineers Western Meeting, San Francisco, March 1960.

THIS ARTICLE is comprised of summaries of the technical papers presented at the A.I.S.E. Western Meeting. In "Application of Digital Control Computers to Steel Industry Processes", R.W. Kirkland (General Electric Co., Schenectady, N.Y.) reported that the first digital computer designed for industrial process control was applied to petroleum refining operations in 1958. Today, nine of the 49 similar units being built or installed in various industries are used in the steel industry. These units are used for controlling rolling mills, continuous annealing and heat treating lines, hot strip mills, reversing mills, and electrolytic tin-plate lines. They are expected to reduce operating costs and to insure better metallurgical quality, as well as increase production.

Digital computers can observe, compare, and analyze metallurgical and industrial processes. They are capable of making programed logical decisions, such as collecting and analyzing process data and locating and identifying abnormal or dangerous conditions which could affect the metallurgical or physical characteristics of the product. They can also perform a series of routine operations in precisely programed sequence, compute and print process data in convenient forms (for quality control inspection or plant accounting systems), register and prepare data for inventory reports, classify material according to quality and quantity, and prepare summary production reports by hour, turn, or day.

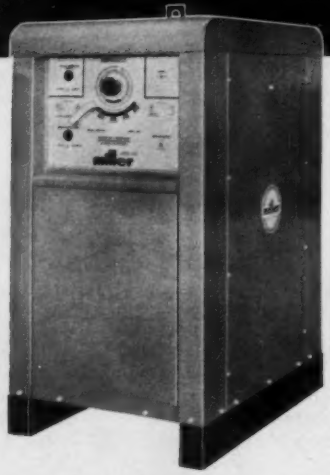
Digital computers in practice have shown 99.75% reliability for a six-month period, 24 hr. per day, seven days per week. With an adequate testing and maintenance program, a figure approaching 100% for every 20-turn period can be achieved.

Next, T. M. Stout and S. M. Roberts (Thompson - Ramo - Wool - dridge Co., Beverly Hills, Calif.) described the use of open-loop sequence control, ranging to closed-loop sequence control optimization, involving complicated programs of calculations and sensitive process measurements. Though these more stringent requirements are difficult to apply, solutions of many intricate industrial processes are possible.

Two talks were given on the operation and flexibility requirements for merchant mills. First, H. A. Griffiths (Sheffield Div., Armco Steel Corp., Kansas City, Mo.) described design, construction, and the operation of a three-strand rod and merchant mill, which was capable of operating at a maximum of 6500 ft. per min. *(Cont'd on p. 170)*

NEW

BALANCED WAVE TIG WELDER DELIVERS DEEP, CLEAN "X-RAY" WELDS ON SHEET METAL or PLATE



• A bold new concept in electrical design and circuitry is introduced in the all-new Miller BWC-300MAP. One of several notable results is complete and automatic elimination of the d-c component at all welding currents . . . an essential in certain critical welding applications.

• Due to the specially designed transformer, high arc initiation voltage and unique circuit, arc-outages cannot occur.

• "Fail-safe" voltage reducer automatically lowers the high arc initiation voltage to a low open circuit voltage — even in case of malfunction of the reducer.

• Five independent welding ranges with overlap offer an infinite number of positive, fine current settings — another characteristic of Miller's electrical control that speeds up and simplifies critical welding jobs.

EXCLUSIVES! — found only in new Miller BWC-300MAP:

1. **Perfect balance throughout the entire welding range EVEN DURING CRATER ELIMINATION.**
2. **Arc stability WITHOUT HIGH FREQUENCY at as low as 18 amperes.**

The outstanding versatility of this welder, and the specifics on its various features, are detailed fully on our form #BW-3 — a copy of which will be sent to you promptly upon request.

miller ELECTRIC MANUFACTURING COMPANY, INC. • APPLETON, WISCONSIN

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Circle 479 on Page 48-S

Heat-treating problem?
Profit from the experience of these users

Each of these users had a heat-treating problem. Their problems were different, yet they all took the same first step toward a successful solution. They consulted a Hevi-Duty Sales Engineer . . . wisely.

A Hevi-Duty Sales Engineer is a specialist. He is qualified to recommend equipment for an entire heat processing system — does it nearly every day. And when it comes to specifying equipment, he has no ax to grind. He doesn't have to push any special size or type. Hevi-Duty makes them all — electric or fuel-fired, all sizes, all temperatures. And if none of these fit exactly, Hevi-Duty will quickly adapt or design a unit that will.

If you have a heat-treating problem, be sure to call in a Hevi-Duty Sales Engineer. He'll be glad to come in without obligation and you will probably profit from his recommendations.

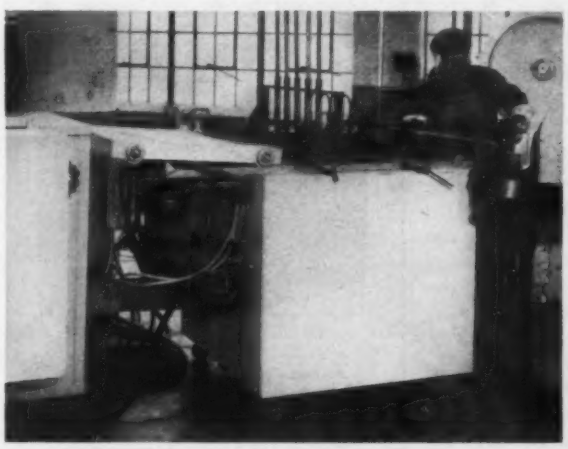
HEVI-DUTY

Electric and Fuel-Fired Industrial Furnaces and Ovens

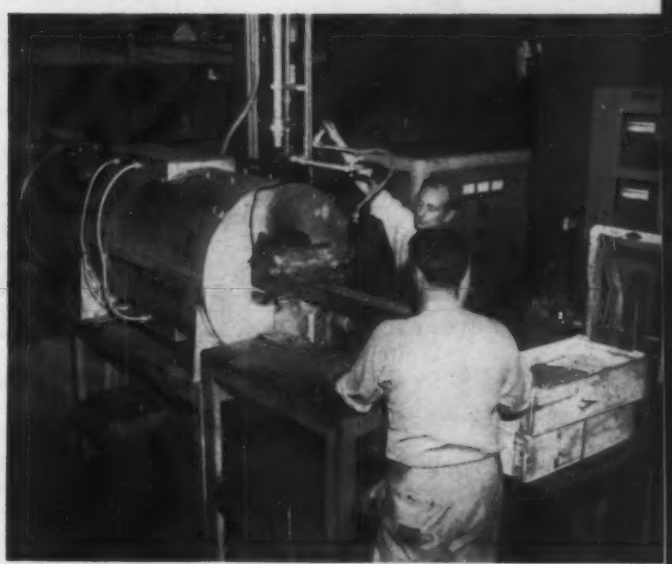
B P C

A Division of Basic Products Corporation

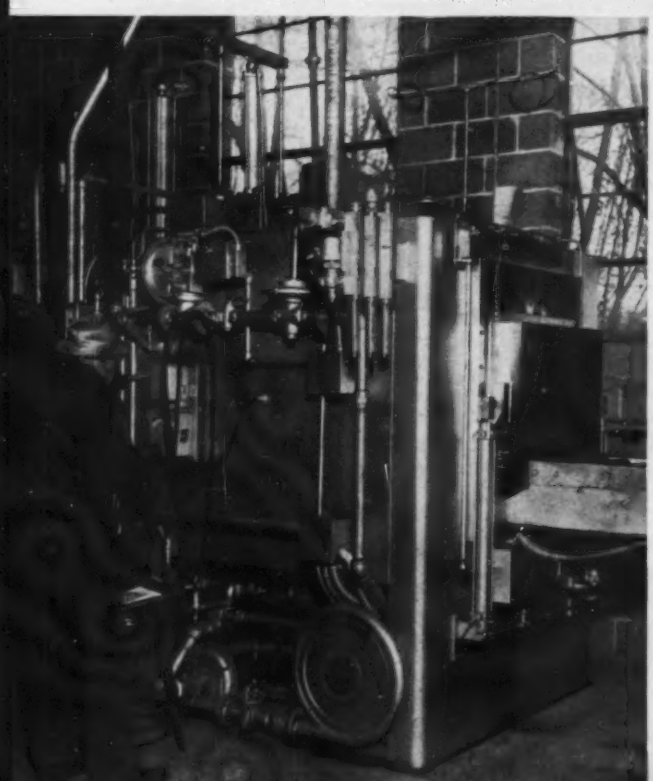
Hevi-Duty Electric Company, Milwaukee 1, Wis.



This immersed electrode salt bath furnace is used at Clevite Research Center, Cleveland. It has a steel pot for low temperatures and a ceramic pot for temperatures up to 2300°F. The furnace is mounted on casters and coupled with a transformer so that it may be used for experimental work anywhere in the shop. ***Please write for Bulletin 655.***

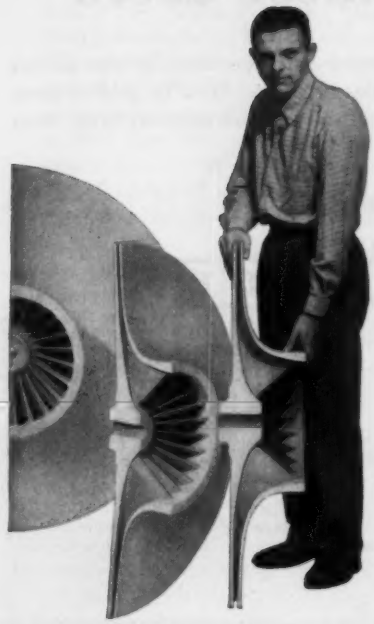


This Hevi-Duty Shaker Hearth Furnace proved to be the profitable answer for Fred Heinzelman & Sons, a New York City commercial heat treater. Small parts are fed onto the hearth and progress through heat and quench cycles automatically. Switching to a shaker eliminated jig and wire time and increased production from 20 to 60 pounds an hour. In addition, the uniform quality of the work has eliminated rejects. ***Please write for Bulletin 1057.***



Ken Ireland, Ireland Heat Treating Company, Orange, Conn., reports a 50 percent reduction in operating costs since switching to this Hevi-Duty Gas-Fired Clean-Line Automatic Heat Treat Unit. One of its jobs is hardening 410 stainless steel knife blades. Knives come out straighter and brighter, with a more consistent hardness than previously achieved. ***For information request Bulletin D-100.***

Circle 480 on Page 48-B



Large aluminum impellers cast smooth and accurate with metallurgical quality for high speed applications are among the specialties of Morris Bean and Company, Yellow Springs 10, Ohio.

BEAN

aluminum
magnesium
ductile iron
foundries

Circle 481 on Page 48-B

Western Meeting . . .

Then, E. C. Peterson and W. H. Boblitz (Birdsboro Corp., Birdsboro, Pa.), in discussing methods for retaining flexibility in the design of mechanized merchant bar mills, mentioned that mill flexibility is the ability to change from one product to another with a minimum of downtime and labor. Flexibility is determined by mill layout, mill design, and roll-pass design.

They consider the Belgian-type merchant bar mill to be the most flexible arrangement. This mill has five stands in train, with a rougher of larger size ahead. It is flexible because (*a*) it is hand-served throughout, (*b*) each stand has multiple passes (passes can be dropped out readily to furnish varying stock for different sizes), (*c*) in complete roll changes, this mill will have the least number of sets to change, (*d*) the roll designer can work with any sequence and size of passes that suit his circumstances, (*e*) bars can be looped for small sections or run out for heavy sections, (*f*) cropping can be done at any point to suit rolling conditions, and (*g*) the roller can readily check the bar section after every pass.

In obtaining highest flexibility, the degree of mechanization of the mill and the tonnage rate must be balanced against the versatility of the equipment. The most flexible unit, therefore, is not the one which is most highly mechanized and which has the highest tonnage rate.

In discussing gage variations, R. B. Sims (Davy and United Engineering Co., Ltd., Sheffield, England), stated that the main cause is the differential between the finishing speed of the last roughing stand and the entry speed of the first finisher. This causes a variation in temperature (and therefore in yield stress) along the coil. It also causes variations in the applied strip tension.

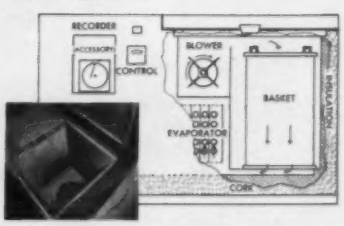
To correct these conditions, the mill should be operated with raised looper rollers and with a constant, small interstand tension. Though this will cause a steady increase in gage from the front to the back (due to temperature changes), it will eliminate rapid gage changes at each end. Accurate speed regulators should be installed on each stand to compensate for motor droop and

HARRIS BASKET CHILLING ATTAINS NEW STABILITY AND HARDNESS FOR NORMA-HOFFMANN BEARINGS

"Our Harris Production Chilling Cabinet attains dimensional stability in our bearings along with a hardness higher than normally obtained by heat stabilization methods," says Richard D. Robertson, Vice President of Manufacturing for Norma-Hoffmann Bearings Corp., Stamford, Conn.

His comment tallies with those of hundreds of other officials of America's foremost manufacturers who are achieving, at the sub-freezing range of the temperature scale, metal properties never possible with conventional heat treating. The reliability of Harris equipment in these applications is testifying to Harris' pioneering background since 1934 in servicing and engineering refrigeration equipment for the most exacting requirements.

Norma-Hoffmann's Harris Model 33L-A2-75 Heavy Duty Chilling Cabinet with solid wall basket refrigerates 500 lbs. of steel from room temperature to -120°F. in 1½ hours with ambient room temperature of 100°F. Total adjustable temperature range is 0°F. to -150°F. Indicating controlling thermostat sensitive to 1°F. One year warranty and 30-day service agreement.



Loose parts easily handled in solid wall basket with screen bottom for efficient air circulation and rapid heat transfer. Blower insures uniform temperature throughout chamber.

ASK HOW CHILLING CAN CUT YOUR COSTS, IMPROVE YOUR PRODUCT

HARRIS MANUFACTURING CO., INC.

306 RIVER ST., CAMBRIDGE 39, MASS.

Pioneer in refrigeration service, engineering, and manufacturing since 1934

Circle 482 on Page 48-B

METALGRAMS

UNION CARBIDE METALS

. . . news of "Electromet" ferroalloys and metals

JULY 1960

NEW LOOK IN FERROALLOYS -- Steelmakers are using greater tonnages of the new forms in which certain alloys are supplied by Union Carbide Metals. For example, refined chrome and 75 per cent ferrosilicon are available as convenient pigs that greatly simplify handling. When added to the furnace or ladle, these pigs give higher metallic yield because no fines are lost in the slag. Their use? Refined chrome is used in stainless steel, aircraft and bearing steels, tool steels, and cast iron. 75 per cent ferrosilicon is a popular open-hearth ladle addition, particularly in electrical steels.

* * *

UNIT-WEIGHT PACKAGES GROW -- A popular packaging feature of many "Electromet" alloys is unit-weight cans and bags. Containing exact weights of alloying elements, these packages provide accurate alloy additions simply by counting out the number of packages required. "Chromtemp" exothermic ferrochrome and "Mantemp" exothermic ferromanganese -- highly efficient ladle addition alloys for open-hearth steels -- are packed in unit-weight cans. So are self-reducing tungsten and self-reducing vanadium, economical alloys for tool and constructional steels. Also, 17 "Electromet" alloys are available in unit-weight bags.

* * *

FORMS PROCESSED IN A VACUUM -- Other alloy forms include bricks and pellets of "Simplex" ferrochrome, a widely used low-carbon ferrochrome for stainless steel. These convenient forms are available because the alloy is vacuum-processed to drive carbon down to extremely low levels. Having the lowest carbon content of any ferrochrome available, the alloy aids stainless melters in meeting low-carbon specifications. Also, "Simplex" ferrochrome penetrates the slag and dissolves readily. As an aid to handling, storage, and inventorying, the bricks are packed in new pre-weighed steel-strapped bundles.

* * *

AT YOUR SERVICE -- Improved alloys and packaging techniques are under constant study at Union Carbide Metals. Experienced materials-handling representatives work directly with metal producers to help determine the most efficient and economical types of alloy packaging and handling in individual plants. Their recommendations on traffic, handling, storage, and usage often result in big savings in money, time, space, or material.

* * *

NATION-WIDE FACILITIES -- To meet the demand for a wide variety of alloys and metals, Union Carbide Metals maintains an efficient warehouse and distribution network to serve metal producers throughout the country. Stocks are maintained at 6 plants and 26 warehouses conveniently located near major metal-producing centers. Rail, truck, barge, and boat shipments speed products to customers' plants. Your Union Carbide Metals representative will be glad to give you further information about the products and services described above. Ask for the article, "Electromet Alloys...When, Where, How You Need Them," in the Winter 1959 issue of UNION CARBIDE METALS REVIEW.

* * *

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. In Canada: Union Carbide Canada Limited, Toronto.

"Chromtemp," "Electromet," "Mantemp," "Simplex," and "Union Carbide" are registered trade marks of Union Carbide Corporation.

Western Meeting . . .

insure smooth entry into the rolls.

W. H. Steinheider (Sheffield Div., Armco Steel Corp., Kansas City, Mo.) discussed the manner in which cupola metal increased openhearth production rates. Two cupolas installed in the openhearth have increased production by about 50%. These were installed to supply hot metal in place of cold scrap metal, thus speeding the melting process. By adding 42% desulphurized hot metal to the openhearth charge (instead of the normal charge of 40% cast metal and pig iron and 60% cold steel scrap), this remarkable increase in production was effected.

W. F. Bowers (Kaiser Steel Corp., Fontana, Calif.) described oxygen furnace operation at Fontana. The plant consists of three converters, 18 ft. diameter by 26 ft. high. Capacity is 1,440,000 tons per year. Electrostatic precipitators in this plant cost $5,000,000 to build.

"Orcarb Process for the Direct Reduction of Iron Ore" was described by W. R. Braddock (Swindell-Dressler Corp., Pittsburgh). A pilot plant has been built and is now continuously producing pig iron from ore, flux and coal. Ore is first mixed with carbon and flux. The agglomerate is then pre-reduced in a rotary kiln, and smelted in an electric furnace.

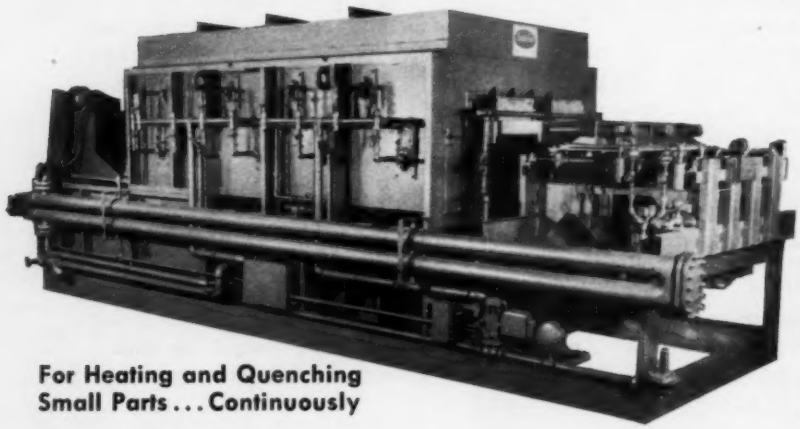
The main advantage of this process is the "one-step agglomeration of very fine ore and flux with highly reactive carbon for rapid pre-reduction in the rotary kiln and subsequent low power consumption in the electric furnace". Another advantage is the low cost of constructing the plant. The cost of completed facilities for this process is estimated at about half that for coke ovens, pelletizing or sintering plant, and blast furnace.

C. C. Crawford (Colorado Fuel & Iron Corp., Pueblo, Col.) discussed stretch reducing mill operations at a seamless tube mill. This installation — Mr. Crawford superintends it — is unique for two main reasons. First, it is one of the two mills operating in the United States where tubing is produced from a reeled shell; second, large shells up to 7⅝ in. in diameter can be stretch reduced on this mill. This mill produces seamless oil well tubing 2⅜ and 2⅞ in. in diameter, from a 6-in. shell, and 4½ in. casings from 7-in. shells.

W. E. Schwabe (National Carbon Co. Div., Union Carbide Corp., Niagara Falls, N.Y.) discussed the fundamentals of heat distribution and refractory wear in electric steel furnaces. The distribution of arc heat radiation on the sidewalls and roof of an electric furnace can be analyzed by a photo-electric analogue method. This method gives more realistic results than the strictly mathematical methods heretofore used.

Hot spots in furnace linings are due to heat concentrations in certain areas near the electrodes, and electrical unbalance accentuates heat concentrations mostly in one of two critical hot spots. There are several methods of equalizing the heat in furnaces, such as establishing power

THE NEW Sunbeam SHUFFLE HEARTH FURNACE



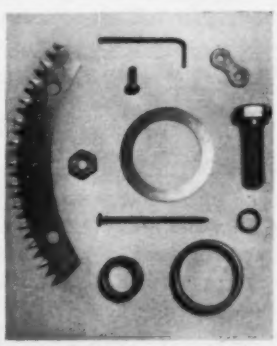
For Heating and Quenching Small Parts . . . Continuously

Now You Can Increase Production, Improve Quality, Reduce Labor

The all new Sunbeam Shuffle Hearth Furnace is designed for production heating and quenching of parts such as those illustrated to the right. Parts similar to these must be processed in quantity to be economical and the finished pieces must be of uniform high quality. The Sunbeam Shuffle Hearth is made to order for these requirements.

Automatic heat treating and quenching make this furnace easy to operate. Only a minimum of supervision and maintenance is needed.

From the sizes available, you can select just the right unit—for maximum production at minimum cost. Choose any size and you will get the savings of a standard unit. Sunbeam Shuffle Hearth Furnaces are already engineered. They can be built, delivered and installed in a short period of time.



Typical parts processed in the new Sunbeam Shuffle Hearth

SEE IT IN ACTION SOON. *To see this new furnace in action we invite you to visit our Meadville plant where we have a production unit in operation. To arrange for a visit or further information, call or write: Mr. Jonathan Smith, Project Manager.*

Sunbeam **SUNBEAM EQUIPMENT CORPORATION**

194 Mercer Street — Meadville, Pennsylvania

Circle 483 on Page 48-B

Who makes and meets your Wire Cloth Specs?

CAMBRIDGE does . . .

To assure you of wire cloth fabrications that give long and satisfactory performance, we have experienced engineers who can draw up prints for your approval if necessary, and trained production men who can quickly and accurately fabricate parts to your most rigid specifications.

To fill your most diversified bulk wire cloth needs, we have thousands of items in stock—in all meshes, wire sizes, metals or alloys—ready for prompt delivery.

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We make wire cloth from any metal or alloy—including titanium—in nine basic weaves—from finest to coarsest mesh. Call your Cambridge Field Engineer for information. He's listed in the yellow pages under "Wire Cloth". Or, write for FREE 94-PAGE CATALOG.

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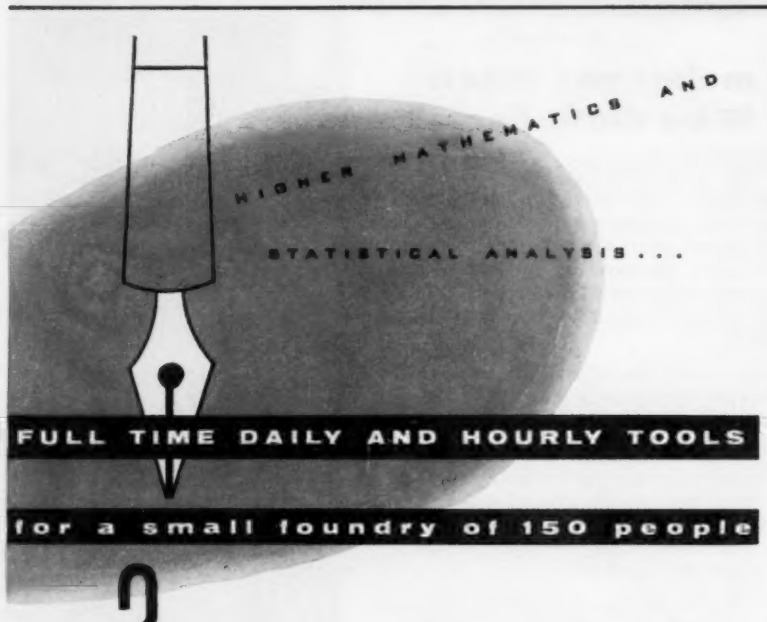
Manufacturers of Wire Cloth, Metal-Mesh Conveyor Belts, Wire Cloth Fabrications

Circle 484 on Page 48-B

Western Meeting . . .

balance by using water cooled flexible cables, repositioning of electrodes, and equalizing the power input into the furnace. If these conditions are observed and hot spot conditions are minimized, service life of the refractory linings can be appreciably extended.

W. G. Ritter (Ritter Engineering Co., Pittsburgh) gave an interesting discussion on lubrication and recommended that: management become more lubrication-conscious; competent and responsible lubrication engineers be assigned; and interest be created in lubrication engineering by promoting from this group. Other suggestions: Create a training program to develop more lubrication engineers; conduct programs to make plant personnel more lubrication-conscious; modernize lubrication techniques; redirect management thinking toward allocating funds for an adequate lubrication program; determine the type of lubrication program which will function most effectively in each particular operation; and assign responsibility for lubrication to those who operate equipment. Mr. Ritter also mentioned that a 100% lubrication system should be used – avoid neglecting equipment which may not need as consistent attention as others. Lubrication systems should be automatic wherever possible to reduce the human factor. Monitoring recorders for lubricant flow, signal lights, audio warnings ought to be employed; otherwise, capable inspectors should inspect all systems at regular intervals. R. C. BERTOSSA



2
+2
4

For the critical engineering applications of the diverse industries we serve, many, highly complex ferrous alloys are needed. To produce the castings in high volume, to extremely exacting specifications, our staff includes a higher proportion of permanent, technical specialists than all but a select, few foundries require.

Utilizing advanced statistical analysis techniques and quality control procedures, these expert technicians keep constant control of the manufacturing process from receipt of raw materials to final inspection and shipment. The maintenance of stringent metallurgical, physical, chemical and dimensional casting standards is the hourly responsibility of these highly trained "technical policemen" — among whom are the mathematician, metallurgist, and statistical analyst.

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MAKERS OF QUALITY CASTINGS FOR IMPORTANT COMPONENTS IN THE AUTOMOTIVE, AIRCRAFT, HYDRAULIC, AND SPECIAL MACHINE INDUSTRIES.

ENGINEERING CASTINGS, INC.
MARSHALL, MICHIGAN

Circle 485 on Page 48-B

Homogenizing Duralumin

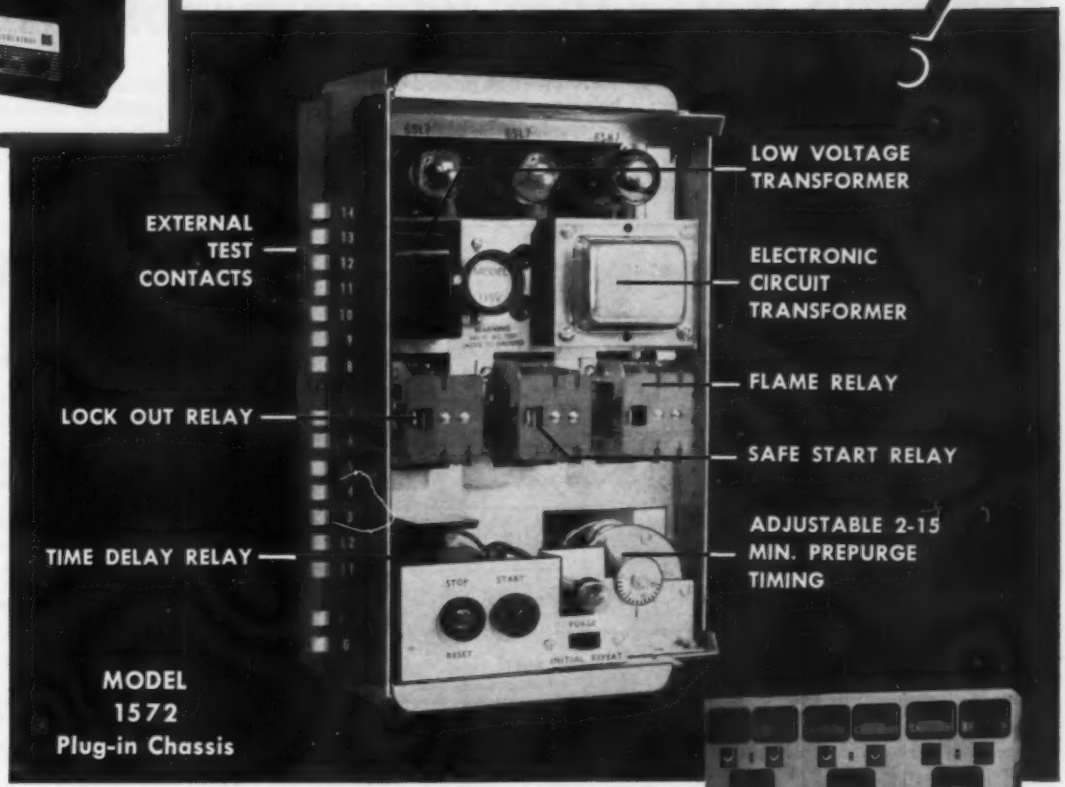
Digest of "Homogenization of Duralumin Ingots in the Latest Model Air Circulation Electric Furnaces", *Tsvetnie Metalli* (*Nonferrous Metals*), No. 4, 1959.

INGOT HOMOGENIZATION is one of the most important operations in production of aluminum alloy sheet. Proper homogenization is necessary to rectify the effects of segregation, nonuniform structure, and properties.

A study was made of the effect of homogenization variables upon properties of two aluminum alloys. One contained 4.25% Cu, 0.65% Mg, 0.6% Mn, 0.30% Fe, 0.50% Si and balance Al (called D-1). The other had 4.5% Cu, 1.5% Mg, 0.6% Mn, 0.30% Fe, 0.25% Si, balance Al (called D-16). The rate of heating, variations in homogenization temperature, soak time at temperature, and the effect of cooling rate were investigated. Since homogenization is essentially a complex diffusion process, these process parameters determine the number and amount of the secondary phases and eutectic mixtures which can be diffused into the solid solution, and thereby enhance its ability to be deformed by pressure.

In prior practice, D-1 and D-16 alloys were homogenized at temperatures of 440 to 460° C. (825 to 860° F.) reached in 20 to 24 hr., then held at this temperature for 2 to 6 hr. However, this treatment was not satisfactory and an improvement in plasticity was desired to permit hot rolling of ingots 200 × 1400 × 5250 to 6010 mm. (8 × 55 × 200

Fire when ready



Automatic Safe-Starts with Wheelco Flame-otrols

Dependable Wheelco Flame-otrols monitor gas, oil or combination flames . . . in small or large furnaces, boilers, kilns and dryers . . . with automatic "flame-out" protection, programmed purging, warm-up proving, pilot proving, and ignition timing. Semi-automatic or manual operation is available. Wheelco Flame-otrols have easy-servicing plug-in chassis, heavy-duty construction, printed circuit boards, standard electronic tubes and external test contacts. *All contacts are visible and accessible during programming.* Your nearby Wheelco office has field-experienced engineers ready to help you . . . call them anytime.

WHEELCO CONTROL CENTERS — Wheelco designs, assembles and prewires control centers to contain all systems for control, indication, recording and alarms . . . for programming all combustion phases (above) . . . or simple flame-off manual-start (below).

THE MARK OF QUALITY

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Circle 486 on Page 48-B

THESE 13 SPECIAL ALLOYS FROM *can help you solve design problems . . .*

As the result of the knowledge gained over the years by working closely with hundreds of customers in helping solve innumerable design and production problems, the Mueller Brass Co. has developed a series of special alloys for use in tough or unusual applications.

This group of special alloys, each having distinct characteristics and advantages, are available in rod form in many sizes and shapes as well as forgings.

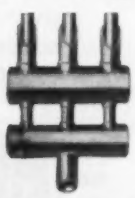
CHARACTERISTICS AND APPLICATIONS	ALLOY NO.	NAME	TEMPER
TUF-STUF® ALUMINUM BRONZES AND NICKEL ALUMINUM BRONZES have great strength characteristics. All are more resistant to corrosion cracking under load than copper-zinc alloys and, in addition, some are heat-treatable. They can withstand heavy pounding and have proved excellent for such parts as gibs, cams, valve seat inserts, shifting forks and propeller hub cones.	224E-30	"Tuf-Stuf" Aluminum Bronze	BRINELL 1000 KG load 165
	224E-75	"Tuf-Stuf" Aluminum Bronze	BRINELL 1000 KG load 175
	224C	"Tuf-Stuf" Aluminum Bronze	BRINELL 1000 KG load 185
	224H	"Tuf-Stuf" Aluminum Bronze	BRINELL 1000 KG load 200
	224K	"Tuf-Stuf" Nickel Aluminum Bronze	BRINELL 3000 KG load 250
ALUMINUM SILICON BRONZE is free turning; has high strength, is corrosion resistant and non-magnetic and resistant to corrosion cracking under load.	802	Aluminum Silicon Bronze	ROCKWELL-B 75
600 SERIES® FORGEABLE BEARING ALLOYS range from high strength to low leaded ductile. All are corrosion resistant, free cutting, can be used with hard or soft mating members and can be soldered. They are employed in a great variety of applications ranging from pump gears and valve stems to pinion shafts and transmission rings.	600	Forgeable Bearing Alloy	ROCKWELL-B 88
	601	Forgeable Bearing Alloy	ROCKWELL-B 87
	602	Leaded Forgeable Bearing Alloy	ROCKWELL-B 87
	604	High Leaded Forgeable Bearing Alloy	ROCKWELL-B 86
	605	Low Leaded Forgeable Bearing Alloy	ROCKWELL-B 80
MANGANESE BRONZE ALLOYS are exceptionally strong, tough, resistant to shock and corrosion. Good for screw machine products and forgings for aircraft parts.	241A	Manganese Bronze A	ROCKWELL-B 85
	721	Manganese Bronze High Tensile Grade B	BRINELL 1000 KG load 200
TELLURIUM COPPER has very high electrical and thermal conductivity combined with good corrosion resistance and machinability. Excellent for electronic components.	799	Tellurium Copper	ROCKWELL-B 45

NOTE: The values shown are average values normally obtained in production. Variations must be expected in practice. The values should be used as a general guide rather than the basis for specifications.

ONE DEPENDABLE SOURCE FOR

COLD-PREST® IMPACT EXTRUSIONS

SINTEEL® POWDERED METAL PARTS



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MUELLER BRASS CO.

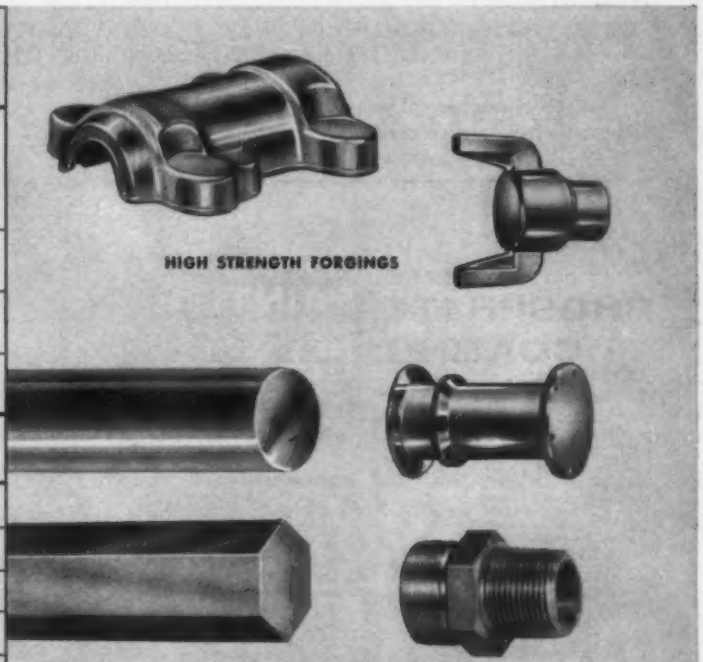
THE MUELLER BRASS CO.

lower costs and improve your products

Mueller Brass Co. engineers and metallurgists are always ready to assist in the selection of the proper alloy for your particular product.

Regardless of your responsibility... design, specification, production or purchasing... Mueller Brass Co. special alloys can help you lower costs and improve your products. Call the "Man From Mueller Brass Co." today and put these remarkable alloys to work on your toughest jobs.

Yield Strength at 0.5% Extension Lbs./Sq. In.	Tensile Strength Lbs./Sq. In.	Relative Machinability Free Cutting Brass=100%
50,000	82,000	30
65,000	100,000	30
62,000	95,000	35
70,000	90,000	30
65,000	105,000	20
35,000	85,000	60
60,000	90,000	25
55,000	78,000	35
65,000	85,000	65
55,000	75,000	80
45,000	70,000	55
55,000	78,000	25
68,000	115,000	35
40,000	43,000	90



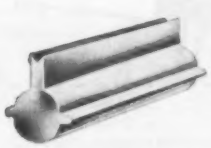
HIGH STRENGTH FORGINGS

ROD SHAPES FOR SCREW MACHINE PRODUCTS

For further information on these alloys write today for Special Alloys Kit No. 13. Engineering information on other fabricated products is also available... please specify the manual you desire.

ALL THESE QUALITY PRODUCTS

SAND CASTINGS



CUSTOM EXTRUDED PLASTIC SHAPES AND INJECTION MOLDINGS

MADE IN U.S.A. TO THE STANDARDS OF AMERICAN INDUSTRY

PORT HURON 28, MICHIGAN

301

Circle 487 on Page 48-B

Duralumin . . .

to 245 in.) without edge shearing, and subsequent cold rolling without intermediate anneals.

Time at temperature greatly affects plasticity and, to a lesser extent, tensile strength. For example, the elongation of unhomogenized D-1 is 2.7%, increasing to 8.0% after 36 hr. at 490° C. (900° F.). Unhomogenized D-16 elongation is 2.6%, but after 36 hr. at the same temperature, it is 7.9%. Also 6 hr. at 440 to 460° C. (825 to 860° F.) produces no significant improvements in ductility.

Analysis of mechanical properties, microstructure and observation of metal behavior during hot rolling led to a conclusion that 6 to 12 hr. at 500 ± 5° C. (932 ± 10° F.) produces optimum plasticity, and will assure satisfactory hot and cold rolling. This practice made rolling without edge shearing and intermediate annealing possible, with increased yields of 7 to 8%. The use of this new technique may cut down annealing periods for certain thicknesses. It was also determined that with finish hot rolling at 300 to 400° C. (570 to 750° F.) cooling in special chambers down to 240 to 250° C. (460 to 480° F.) will produce sufficient ductility.

Future developments will aim at:

1. Increased hot and cold rolling rates and shorter passes.

2. Adoption of temperature-rolling speed control during deformation to eliminate the preliminary anneal before cold rolling.

3. Installation of edge rolls to improve the edge quality and shorten the hot rolling cycle.

4. Use of flying shears to cut the ends of hot rolled strip and to permit rolling while coiling.

5. Use of a coiler with a belt wrapper to allow rolling while coiling.

6. Cold rolling at speeds up to 10 m. per sec. (32.8 ft. per sec.).

7. Placement of two levelers into the line: one for 2 to 4-mm. sheets and one for 0.5 to 1.5-mm. sheets.

8. Use of temper mills with tension to achieve single skin passing.

9. Elimination of the sheet stretching operation.

ARTHUR B. TESMEN

Here's the
PHOSPHATE COATING
You asked **TURCO TO MAKE**

HERE'S HOW **PAINTITE** SCORES ON SURVEY'S 12 "MOST WANTED" FEATURES

Formulated as Result of Industry-Wide Survey...

During the first six months of 1959, Turco undertook an extensive survey of the phosphate coating market. Hundreds of users of these coatings were interviewed. Thousands of questions were asked. When the answers were tabulated, Turco began the task of building an iron phosphate process to the *exact specifications* called out in the survey.

The new process is now available. It is called Turco Paintite. Paintite has been thoroughly field-tested in the production lines of a dozen Turco customers. It has passed the most severe tests with flying colors. Turco is proud to announce the addition of Paintite to its ten other Turcoat phosphate and conversion coating processes that provide a better bond for organic finishing.

1. **SUPERIOR CLEANING**–Exclusive wetting system provides heavy-duty uniform cleaning. Cleans & phosphates simultaneously.
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Circle 488 on Page 48-B

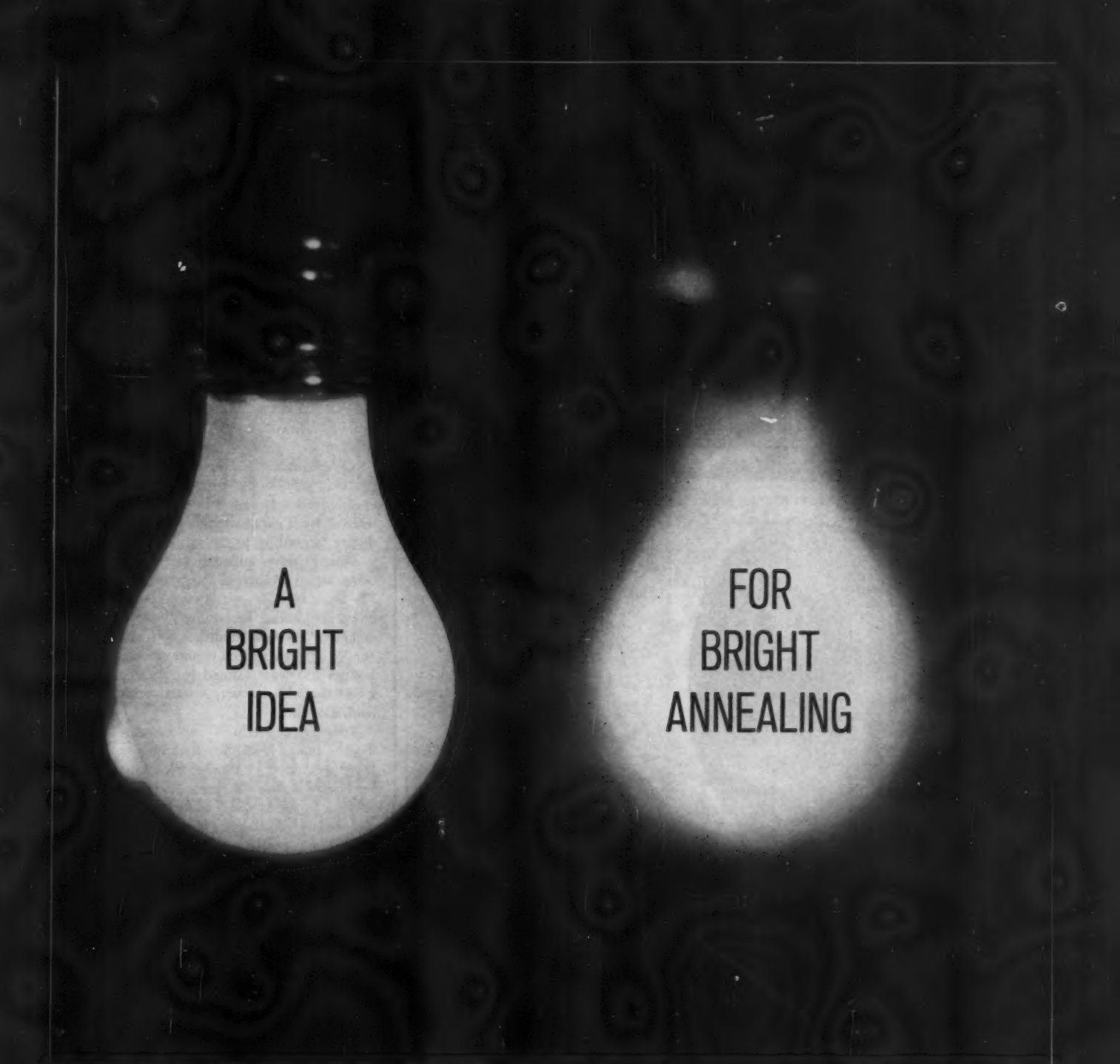
Advances in Chromium Plating

Digest of "Recent Developments in Chromium Plating", by D. E. Weimer, *Metal Finishing Journal*, March 1959, p. 89-97.

SIX MAJOR ADVANCES in chromium plating technology during the past five years were designated by the authors:

1. A fuller understanding of the effect of heat treatment on the properties of chromium has been developed. For example, the effect of heating on the fatigue strength of chromium-plated steel and the relationships of fatigue strength, stress in the plate, and the crack structure of the chromium have been recognized. The author reviews the evidence showing that the fatigue strength of chromium-plated steel can be restored to the strength of unplated steel by heating at 968° F. (520° C.), but pointed out that the hardness of the chromium was reduced by 15%.

2. An appreciation of the nature and mode of the formation of cracks in chromium plate was attributed, in part, to the independent researches at British Non-Ferrous Metals Research Assoc., Udylite Corp., and Metal & Thermit Corp. The development of two processes for depositing bright, crack-free chromium at least 0.0001 in. thick was discussed. The improvement



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Circle 489 on Page 48-B

Cr Plating . . .

in the corrosion performance of nickel and chromium-plated parts afforded by plating crack-free chromium in place of ordinary chromium was established by corrosion tests conducted by the author. Two procedures for depositing even thicker chromium in a crack-free, but dull, condition were reviewed. One employs solutions containing both sulphate and fluosilicate ions. The other uses selenic acid as an addition agent. Both are done at a high temperature.

3. The installation of the first commercially operated solutions for the production of crackfree chromium rapidly followed laboratory and pilot-plant developments. Production experience has indicated that 0.000035 in. is a reasonable average chromium thickness for obtaining good corrosion resistance with bright nickel-chromium composites.

4. The acceptance of spray depressants as a replacement for fume extraction has been noteworthy. Supplemental advantages include a reduction in the corrosion of busbars and other equipment, and the reduction of drag-out losses. Their unsuitability for hard chromium plating was noted, however, because the depressants give rise to pitting in thick deposits.

5. The increased application of high-speed solutions for hard chromium plating have largely been patterned on sulphate-fluosilicate solutions employing salts that control the solubility of the sulphate and fluosilicate at a given temperature. Baths containing these salts have therefore been designated as self-regulating.

6. A complete appreciation of the practicability of self-regulation in chromium solutions has been demonstrated by their acceptance by industry, according to the author.

Among developments in anode composition, industrial acceptance of 7% Sn lead alloy was noted, especially for baths containing fluoride catalysts. New lead-antimony-silver anodes have been announced. Longer life was claimed for anodes when their hooks were coated with lead alloy.

Treating procedures for increasing the life of lead alloy tank linings were discussed. Anodic treatment for new linings is recommended. After a protective film is formed on the lining, insulating glass linings should be installed.

The harmful effect of impurities in reducing efficiency and covering power was noted. Chloride ions were described as being particularly harmful, even at the low concentration of only 0.05 g. per l. To avoid cracking in dull chromium deposited at a temperature of 150° F., chloride ion concentration must be kept below 0.03 g. per l.

Some of the author's 14 references were directed to discussions of a theoretical nature. Topics included the role of the catalyst, the role of trivalent chromium, the periodicity of fluctuations in hydrogen evolution and the relationship between this periodicity and that for cracking in chromium. Rousselot's efforts in establishing the interdependency of chromic acid concentration, catalyst concentration, solution temperature, current density, and the concentration of impurities were also noted by the author.

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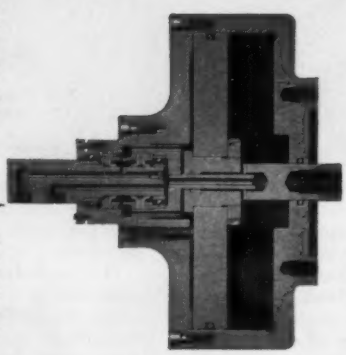

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Circle 490 on Page 48-B

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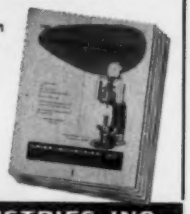

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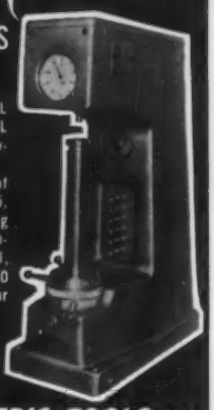

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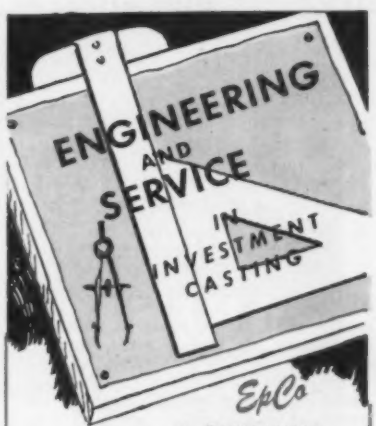

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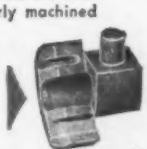

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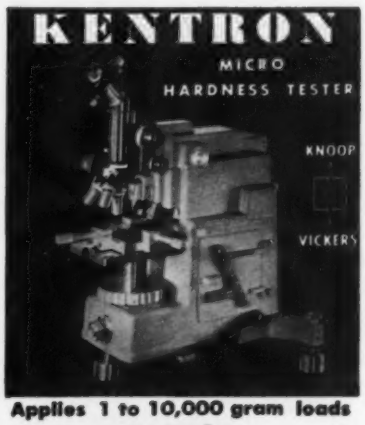

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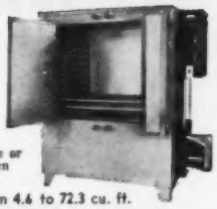

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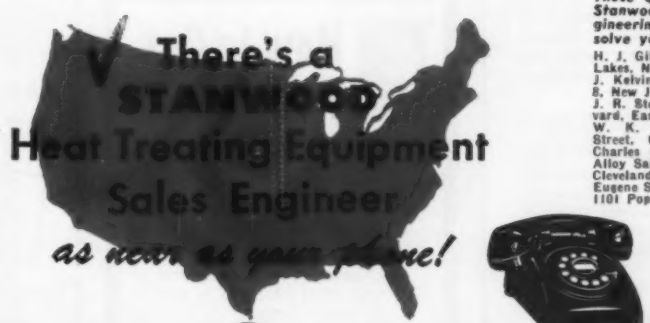
William McAtee, 626 N. DeQuincy St., Indianapolis 1, Indiana.
Harry I. Dixon, Metallurgical Products Co., 1199 Beacon St., Brookline 46, Mass.
Carl H. Schmidt Co., 16405 W. 8 Mile Rd., Detroit 35, Mich.
A. A. Gustafson, 161 Griggs — Midway Bldg., Fairview at University, St. Paul 4, Minnesota.
The Shea-Brownell Co., 3903 Olive Street, St. Louis 8, Missouri.



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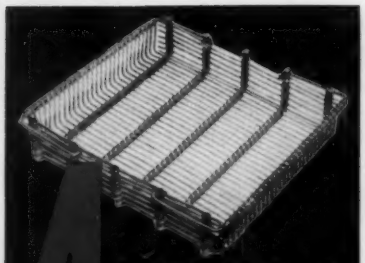
J. Kelvin Stahl, 716 River Road, Trenton 8, New Jersey.
J. R. Stewart Co., Inc., 2900 Erie Boulevard, East Syracuse 3, New York.
W. K. Hile Company, 1236 Morehead Street, Charlotte 7, N.C.
Charles Plant Jr. and Warren B. Lum, Alloy Sales & Service, 8905 Lake Avenue, Cleveland 2, Ohio.
Eugene S. Craig, Craig Indust. Equip. Co., 1101 Popular Ave., Memphis 4, Tennessee.
Gipson Supply Co., 122 Grant Ave., Pittsburgh 9, Pa.
M. K. Griggs Co., Inc., 5523 Dyer St., Dallas 6, Texas. 2801 San Jacinto, Houston 4, Texas.
Robert M. Onan Co., 5138 North 35th St., Milwaukee 9, Wisconsin.

STANWOOD CORPORATION
4817 W. CORTLAND STREET CHICAGO 39, ILLINOIS

Circle 22 on Page 48-A



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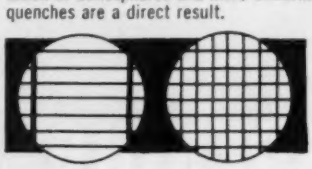
bixco FABRICATED HEAT-TREAT BASKETS

1 MORE OPEN AREA

Our unique looped wire liner (with slotted openings) affords 30% to 100% greater open area than conventional liners. Faster heats, greater circulation of atmospheres and more uniform quenches are a direct result.



bixco BUILT-IN Looped Wire Liner — Conventional Liner

2 LESS WEIGHT

In the Economy 6 Series with built-in liner and round rod framing, total basket weight is kept to an absolute minimum without sacrificing high strength.

3 TRUE ECONOMY

Our many exclusive features bring basket maintenance and furnace operating costs DOWN. Bixco baskets perform better because they are made better.

4 SPACE AGE ENGINEERING

Meeting the demands for better baskets is a Bix Company specialty. Besides fabricating in all standard metals we also produce baskets of Molybdenum. Special designs and applications are available on request.

For complete information write:

bix COMPANY
FAIRGROUNDS ROAD
WELLINGTON, OHIO

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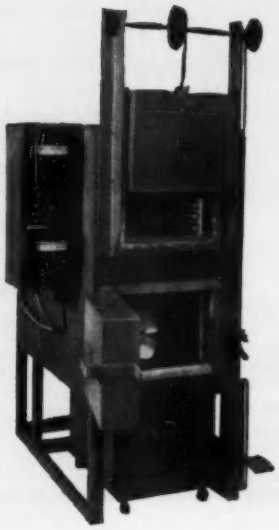

LUCIFER "SPACE-SAVER" COMBINATION HEAT TREATING FURNACES

Two series (8012 and 8008) of "space-saver" combination heat treating furnaces are produced by Lucifer Furnaces, Inc. Hardening, drawing or preheating, and quenching operations can be performed with one furnace. Each furnace has separate controls permitting independent operation of each unit. The 8012 series chambers operate at 2300, 2000 and 1250° F.; while the 8008 series chambers reach 2300, 2000, and 800° F. The furnaces operate on standard line voltage . . . no transformer necessary. Twenty standard low-cost models are available and each is a complete unit . . . just connect to power supply.

For information about the "space-savers", our complete line, or free engineering advice, call on . . .

LUCIFER FURNACES, INC.
Neshaminy 7, Pennsylvania
Diamond 3-0411

Circle 26 on Page 48-A

How to Cut Pot Costs:

Buy low-cost Eclipse pressed (not welded) steel pots . . . and replace them on a regular schedule.

1 Lower initial cost
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4 Quantity discounts earned on your total purchases in any 12 month period.

Guaranteed free from defects. Write:
Eclipse Fuel Engineering Company
Industrial Combustion Division
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Eclipse PRESSED STEEL POTS

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BRAND NEW FURNACES AT USED PRICES!

	WIDE	LONG	HIGH	TEMP	KW
Car Type	5'	10'	5'	1250° F.	120
Roller Hearth	2'	20'	1'	2100	120
Roller Hearth	4'	18'	2'	1200	GAS
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Roller Hearth	4'	34'	1'	2050	180
Roller Hearth	5'	42'	4'	1500	GAS
Pusher	12"	110"	8"	2000	60
Drever Pusher	14"	120"	7"	2100	120
Harper Pusher	17"	14'	7"	2500	150
West. Pusher	18"	15'	8"	2600	179
Lindberg L. Pusher	15"	30"	12"	2500	80
Ipsen Pusher	24"	34"	18"	1750	GAS
Furnace Eng. Pusher	63"	30'	46"	1800	GAS

ALSO ALL TYPES OF FURNACE ACCESSORIES, PYROMETERS, AND LAB EQUIPMENT. WIRE OR CALL COLLECT!

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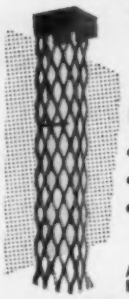
there's a *Glo-QUARTZ* IMMERSION HEATER for Your Every Heating Requirement



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- AVAILABLE IN ALL VOLTAGES —WATTAGES, ONE AND THREE PHASE

Available from your Electroplating Distributor

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*Reg. U.S. Pat. Off. Phone: Willoughby 7-5521

Circle 20 on Page 48-A

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the QUENZINE STORY

Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .

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$99.95 only
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Powerful 40 watt output
Stainless steel tank
Full ½ gal. capacity

DISONTEGRATOR® SYSTEM FORTY
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The lowest priced ultrasonic cleaner ever sold!

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LOW PRICES ON LARGER MODELS!

System No.	Power Output (Watts)	Tank Capacity Gallons	Tank Dimensions	Price
80	80	1½	12 x 6 x 6	$ 199.95
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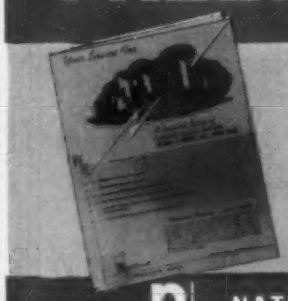
520	520	10	20 x 10 x 10	999.95
1040	1040	30	24 x 18 x 16	1,999.95
3000	3000	75	31 x 31 x 18	3,999.95

Circle 32 on Page 48-A

FREE! ULTRASONIC CLEANING BULLETIN



Describes National Ultrasonic Corporation's:

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Interested in modernizing your production? Get this handy reference guide on epoxy adhesives, coatings, sealants, and plastic alloys . . . without cost or obligation.

Just write us on your company letterhead and ask for a complimentary copy of Resiweld Book #2.

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FASTER, BETTER FLAW DETECTION WITH ULTRASONIC SONORAY® 5 AND SONOGATE FLAW ALARM

Set the accessory plug-in Sonogate for any desired critical size of flaw — scan large areas rapidly with "your eye on the ball" — study the CRT trace only when alerted by the red signal light on the transducer. Ask for Sonoray Bulletin T-200.

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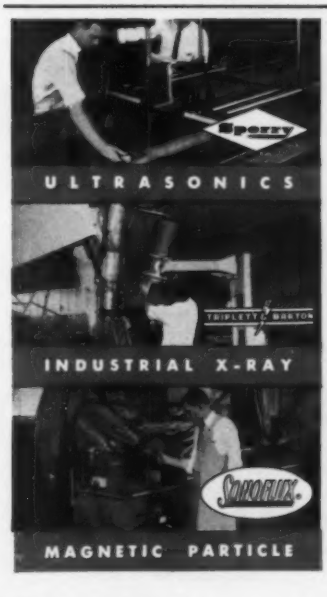

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NONDESTRUCTIVE TESTING SERVICES

A complete service providing day to day nondestructive testing for the detection of flaws in materials in the field or at one of Sperry's laboratories.

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SPERRY PRODUCTS COMPANY DIVISION OF HOWE SOUND DANBURY, CONN.

Circle 30 on Page 48-A

Before you buy another extrusion... CHECK THIS LIST

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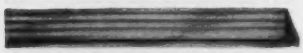
We'll give you a clear surface free of "pick-up" . . . close tolerances . . . expert handling . . . packaging to your specifications.

DIE SERVICE

We'll give you fast, skilled die service from craftsmen who have fine equipment to work with.

ANODIZING

We'll give you high quality anodizing using 26' tanks to meet your maximum requirements. Color anodizing also available.



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We'll give you quick delivery on small orders as well as big orders. We'll help you keep your production schedule.

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Tell us what you want. We have the people and the facilities to do it.

We are also a skilled producer of precision aluminum mouldings.

WHY NOT WRITE US TODAY.

Aluminum Extruders • Anodizers • Artrim Mouldings

SUPERIOR INDUSTRIES INC.

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RUST-LICK

IN AQUEOUS SYSTEMS

Eliminates RUST & Fire Hazards Non-Flammable Non-Toxic

Send for Brochure:
The ABC of Rust-Lick for Rust Prevention

RUST-LICK, INCORPORATED
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BOSTON 16, MASS

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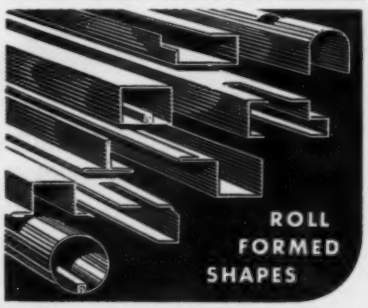

Reduce your assembly problems and costs. Our shapes continuously formed, with high degree of accuracy, from ferrous or non-ferrous metals. Write for Catalog No. 1053.

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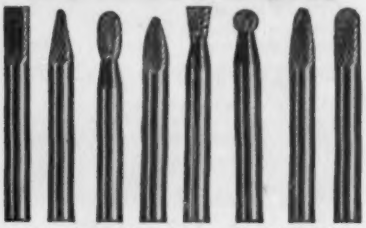
MARTINDALE

ROTARY BURS



Solve toughest metal-cutting jobs. Martindale Carbide Rotary Burs and Files cut the toughest metals and abrasive materials. Precision ground from solid carbide, in wide selection of shapes and sizes 3/32 to 1 in. diameter. Available in identical shapes, sizes in high-speed steel.

Send for NEW CATALOG including hundreds of cost-saving items for maintenance, safety, production.

MARTINDALE ELECTRIC CO.

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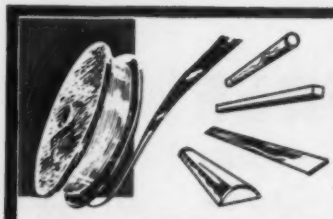

ROUND, SQUARE, FLAT AND HALF-ROUND WIRE FOR MASS PRODUCTION OF SMALL PARTS

Beryllium Copper • Bronzes
Other Non-ferrous Alloys
Rounded or square edges.
Available with hot-tinned finish for solderability.
Write for descriptive folder.

LITTLE FALLS ALLOYS
INCORPORATED
193 Caldwell Ave., Paterson 1, N. J.

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WELDING STAINLESS?

Contact "Whitey" (Mr. Electrode)

Whitey knows the ropes when it comes to welding stainless . . . and he's happy to help with your welding operations. His years of experience, plus the trusted welding materials of Maurath, add up to a guarantee of quality welding. Call Maurath for stainless and heat resistant arc welding electrodes of all analyses . . . coated, straightened . . . cut . . . coiled and spooled. The most complete plant in the industry . . . From 1/2 in. diameter, bars reduced to 0.045 in. wire.

Quality and Service Are Remembered
Long After Price Is Forgotten

MAURATH incorporated
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Phone: MOntrose 2-6100

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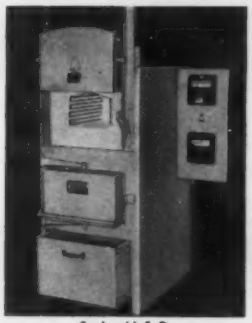
ELECTRA HEAT TREATING FURNACES

Combination Models—Series H and D

Hardening Range ..... 2000° F and 2300° F
Drawing Range ..... 800° F and 1250° F
Four Standard Models ..... or special design to suit



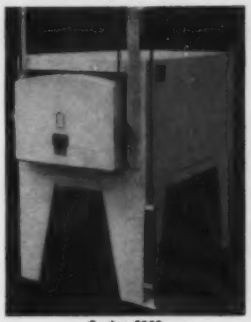
Series H & D

General Purpose Box Models
Series 2000 and 2300
Ten models 2000° F and 2300° F range

All standard models include an automatic indicating controller and are wired ready to operate on standard line voltage. *Write for bulletins A-59 and B-59.*

Electra Products manufactures furnaces for semiconductor diffusion processes, sintering, glass annealing and processes requiring temperatures up to 3000° F.

Inquiries are invited—no obligation
Territories available for representatives



Series 2000

ELECTRA PRODUCTS CO. **Montgomeryville, Pa.**

Circle 47 on Page 48-A

RAMCO
modular power spray washers

☑ MAXIMUM PERFORMANCE
☑ MAXIMUM ECONOMY

Proof? In this Ramco Bulletin . . . shows how you can create the *right* system for today's . . . and tomorrow's needs. *Send for your copy* NOW! Ask for Bulletin 659-I.

RAMCO EQUIPMENT CORP.
DIV. OF RANDALL MFG. CO., INC.
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CORROSION RESISTANT
647 Union Blvd., Paterson 2, N. J.
CLifford 6-2300 • TWX: LTFSNJ-1382
Direct N.Y. 'phone Wisconsin 7-6310
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Circle 43 on Page 48-A

FOR **ACCURATE** Rockwell hardness testing, use Wilson "Brale" Diamond Penetrators

- Every Wilson "Brale" Diamond Penetrator is identical in angle and radius.
- Only flawless diamonds, free from cracks or chips, are used.
- Microscopic inspection and a comparator test of each diamond assures consistent quality.
- Each penetrator is proof-tested under heavy load.
- Special penetrators available for testing unusual areas.

Write for Catalog RT-58 for details on Wilson "Brale" Penetrators plus the complete line of Wilson Rockwell hardness testers.

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Wilson Mechanical Instrument Division
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American Chain & Cable Company, Inc.
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Circle 45 on Page 48-A

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SPECIALISTS IN THE FIELD OF
Die Castings
SINCE 1922
Aluminum and Zinc

THE HOOVER COMPANY
Die Castings Division
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All The Best

HEAT RESISTING ALLOYS

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Please Send for Stock List and Literature

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Circle 44 on Page 48-A

SECURITY

Is A Sunday Picnic That Is Free From Worries Of Monday

Security results in the feeling that you're doing your best to be a good provider. But being that thoughtful breadwinner is not an easy job. You've got to keep an eye on the future and at the same time use the present for all it is worth.

This may be true in your case. You are part of an industry that is advancing in great, leaping strides . . . leaving behind it a pile of outdated methods, unusable tools and shop-worn formulas. More severe, industrial progress is leaving behind the men who can't keep up the pace, who stop learning. For them, security is in doubt.

How do you feel? . . . secure enough to say that a little studying at home won't make you more capable on the job? Secure enough to say that more education isn't necessary to your career in industry . . . that you will advance to the job you want —in the field you want—with the knowledge of metals and processing you now have? Secure enough to stop learning?

Listed below are the home study courses now offered by ASM's Metals Engineering Institute. These courses have earned the respect of thousands who have enrolled in MEI. They offer comprehensive instruction of very high caliber. In these courses you can find the additional training that results in more security for you and those who depend on you.

Elements of Metallurgy
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Titanium
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Welding Metallurgy
Heat Treating Principles
Corrosion
Magnesium

Return the coupon at right for your MEI catalog which describes each course in detail—authors, lesson titles and descriptions. A catalog will be sent at no obligation.

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STREET_____

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COURSE OF INTEREST_____

Metals Engineering Institute

AMERICAN SOCIETY FOR METALS
METALS PARK, NOVELTY, OHIO

AGAIN

P-K Internal-Fin Coolers can be furnished insulated with Rock Cork laid in asphalt and covered with a heavy steel jacket. Illustration shows insulated cooler.

Revere helps fit the metal to the job

AND PATTERSON-KELLEY CUSTOMERS SAVE 3 WAYS

Because of its unique design, the Patterson-Kelley Freon Water Cooler shown at right above saves space, requires less Freon, while its reduced weight and size mean lower cost.

With the P-K Type FO Internal-Fin Freon 22 Water Cooler the installation can be designed for a shell 2 diameters less and 1 to 2 feet shorter than with conventional plain or bare tube coolers. This is made possible by the use of ¾" O.D. x .035" gauge Revere copper tube drawn over a Revere aluminum extruded fin as shown above. Serrated surface of the fin enhances refrigerant vaporization.

By making both the tube and the extruded fin, and assembling them in the same plant a tight contact between the two metals is assured, thus establishing maximum heat transfer. Once again Revere has helped fit the metal to the job, money was saved and a more efficient product produced.

Why not consult with Revere's Technical Advisory Service and take advantage of its extensive knowledge in "fitting the metal to the job." This Service has saved others money, why not you?

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Founded by Paul Revere in 1801
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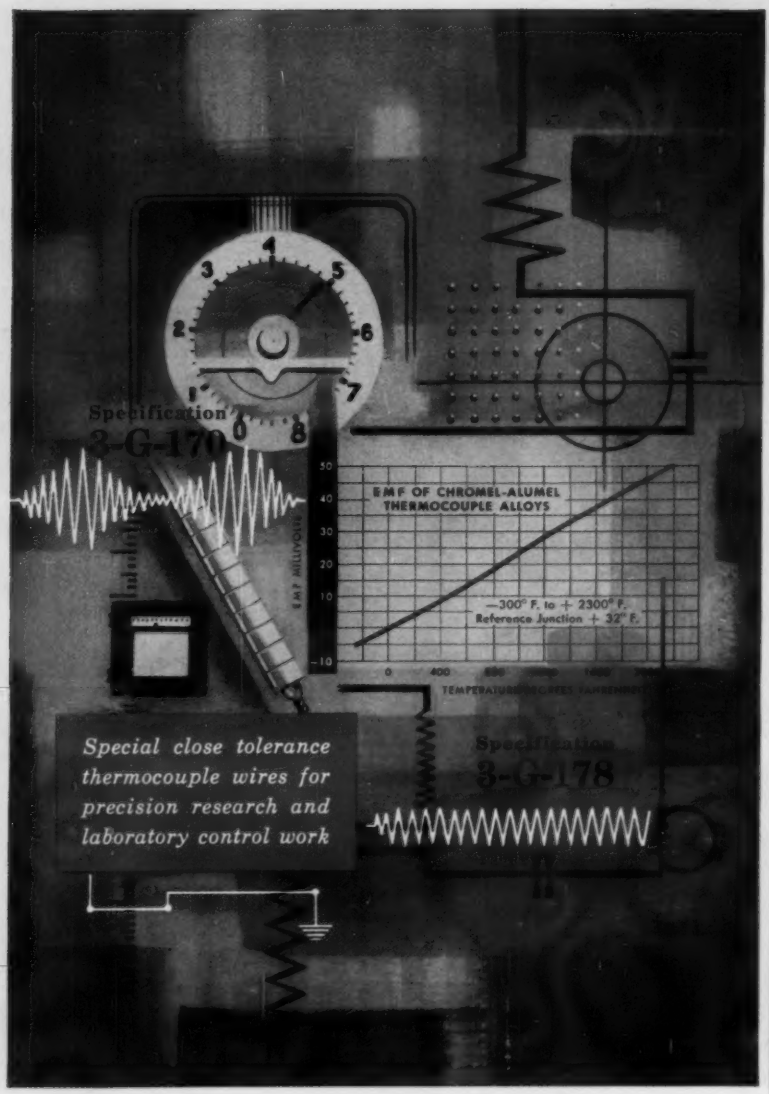
Mills: Rome, N.Y.; Baltimore, Md.; Chicago, Clinton and Joliet, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Brooklyn, N.Y.; Newport, Ark.; Ft. Calhoun, Neb. Sales Offices in Principal Cities. Distributors Everywhere.

Circle 533 on Page 48-B



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Hoskins Chromel-Alumel thermocouple alloys are the world's basic standard of accuracy for controlling the heat treatment of metals—the *only* base metal materials known having established and guaranteed temperature-emf characteristics over a useful operating range from −300° F. for cryogenic applications up to 2300° F. for measuring temperatures in industrial furnaces, nuclear reactors and jet aircraft engines.

Now, in addition to standard guaranteed millivoltage material, these extremely durable, ultra reliable alloys are also being produced in the following special grades for precision quality control:

Specification 3-G-178—Accuracy guaranteed to ½ standard tolerance limits.

Specification 3-G-170—Accuracy guaranteed within ±5° F. over temperature range from 1000° to 2000° F.

Available through instrument manufacturers, thermocouple fabricators, and pyrometer service companies. Write for complete technical data.

***Trade names you can trust for accurate temperature measurement!*

Genuine Chromel and Alumel are produced exclusively by

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4441 Lawton Avenue • Detroit 8, Michigan

Custom-Quality resistance, resistor and thermo-electric alloys since 1908

Circle 534 on Page 48-B

Wear of Nonferrous Metals by Tungsten Carbide

Digest of "Pickup of Copper and Duralumin on Bonded Tungsten Carbide", by J. Golden and G. W. Rowe, *British Journal of Applied Physics*, Vol. 10, August 1959, p. 367-371.

EARLIER EXPERIMENTS on wear have shown that the transfer of bonded tungsten carbide to other metals can be studied in detail by radio-tracer techniques. If surfaces were smooth and uniform, steady wear occurred on copper, mild steel, and stainless steel during single traverse sliding. The wear pattern on aluminum is different, however, the carbide being transferred in irregular patches. The other aspect of wear, the transfer of metal to the carbide, is also important, and these experiments studied the quantitative pickup onto carbide specimens under different conditions.

A modified form of the Bowden-Leben apparatus was used for these experiments. An inactive tungsten-carbide hemisphere was pressed into a radioactive copper slip, and the copper was moved under a known load to make sliding contact for a short distance. The slider was then lifted off the active surface and onto an inactive copper block where sliding contact was again made to form an identical sliding track on the inactive surface. The deposit of active copper was subsequently measured by autoradiography.

The copper slip was irradiated for two days, and sufficient Cu^{64} was generated to enable two days of work to be completed. Experimental work was begun 5 hr. after irradiation. A sample of aluminum (4% Cu and 0.4% each of manganese, magnesium, silicon, and iron) was activated under similar conditions. While the level of activation of the aluminum was less than the copper, it nevertheless enabled pickup to be detected.

Carbide tips were prepared either by polishing with a diamond paste or by polishing followed by etching with alkaline-ferricyanide. Metal slips were finished on 4/0 paper and methanol prior to irradiation. Upon return, the surfaces were treated with 1:1 HCl.

The tip was contacted with the active surface under load and then assessed for pickup. After replacing the tip, a short track was made followed by a measurement of the pickup. Further tracks of increasing length were made until the pickup reached a constant value. A similar procedure was then followed on the inactive metal surface. The autoradiographs were measured with a recording micro-densitometer to obtain quantitative data. The following carbide materials were evaluated against copper after polishing: medium grain size (1 to 2 micron) with 6% cobalt; very coarse grain size (3 to 5 micron) with 6% cobalt; coarse grain size (2 to 4 micron) with 20% cobalt.

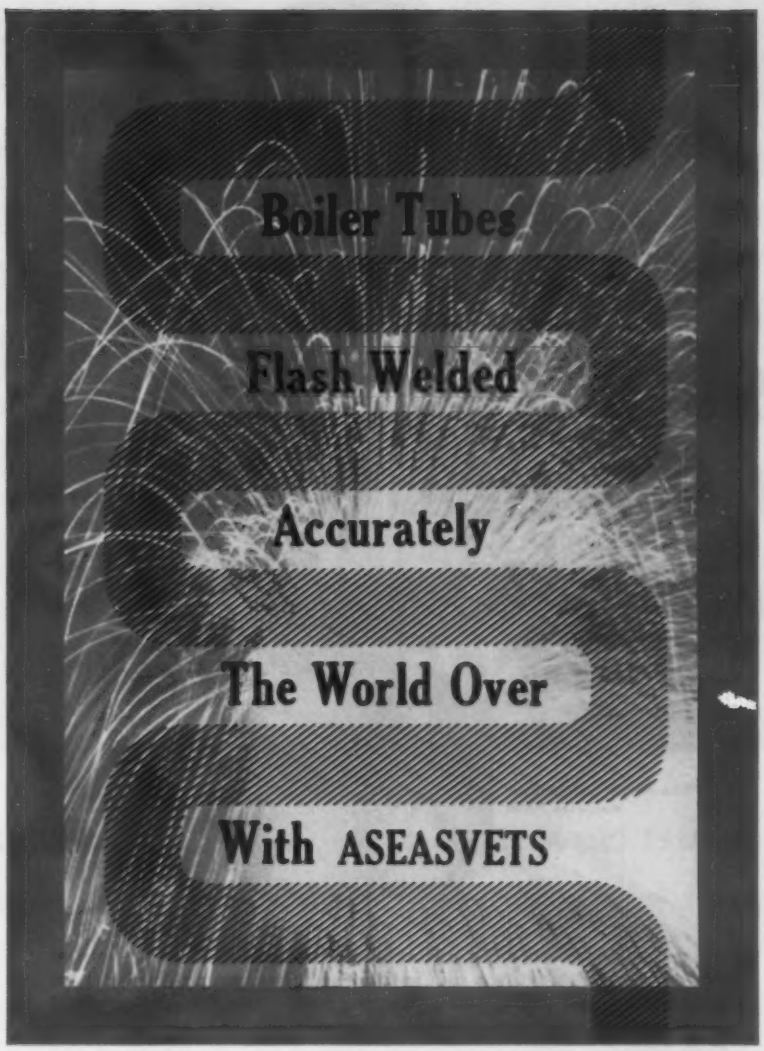
All of these gave the same results. A small amount of copper was picked up over a short sliding distance which remained constant after further sliding. Since the accuracy of measurement is about 0.01 microgram, it is not possible to make valid deductions except to affirm that copper was detectable and that it was less than 0.02 micrograms.

Similar experiments which employed tips polished and then etched indicated that the amount of copper pickup increases uniformly over the first few millimeters of sliding, and then reaches a steady value at least a thousand times as great as the amount found on the polished slider. The surface roughness of the etched tip was found to be a hundred times that of the polished surface.

The etched carbide tip containing the active copper was traced varying distances on an inactive copper surface. Analysis of the data showed that the active copper was removed rapidly. After a few millimeters, only a very small amount was left. It appears there is a continuous transfer, copper being taken from the block while an equivalent amount is redeposited.

Additional experiments were made using a lightly etched tip whose surface roughness was only slightly higher than the polished tips. The copper pickup was about ten times as large as with the polished tips. Redeposition was similar to that experienced with the deeply etched carbide tips.

Similar experiments were conducted with active aluminum. The amount of pickup increased rapidly to a fairly constant but erratic value.



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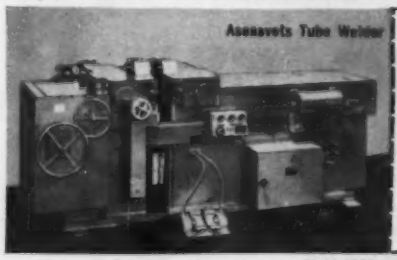

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Nonferrous Metals . . .

These tips and their "shoe" of active aluminum were slid on inactive aluminum. After 30 mm. of sliding, little reduction of the "shoe" could be detected. Neither pickup nor redeposition appeared to be affected by the grain size of the carbide. It appears that after a pickup, the aluminum film persists without change during subsequent sliding.

The continuous transfer of copper suggested by these experiments can possibly be explained by considering that the roughened carbide tip acts as a microscopic file. The hard grains, like the teeth of a file, machine small quantities of copper from the surface. This will continue until the spaces between the "teeth" are filled in. If sliding proceeds beyond the point where the pockets are full, the material in the pockets will be forced to again contact the block and to adhere. While this is a tentative suggestion, it does explain a number of features.

The results of experiments with aluminum show a modified behavior. It may be that the aluminum pickup is unable to slide over the carbide pocket surfaces as easily as copper. Occasionally, a fairly large fragment will be broken away from the build-up, but there is no evidence of the smooth deposition found with copper.

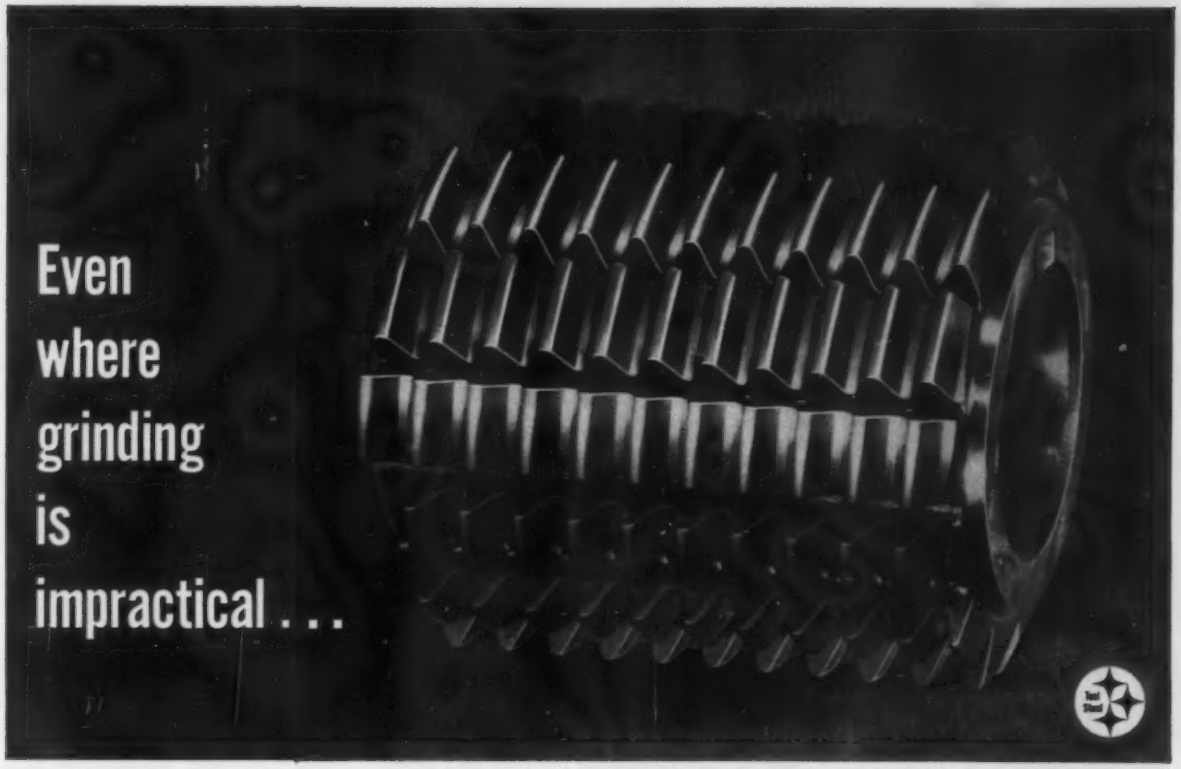
Wear tests have also shown the difference between the behavior of copper and aluminum. The slide tracks on copper were uniformly covered with carbide while those on aluminum showed scattered deposits of small fragments. This suggests that the two processes – transfer of metal to and from carbide, and wear of carbide – are closely associated.

R. F. HARTMANN

Flash Heating

Digest of "Flash Heating — A New Technique", by L. S. Nelson, *Chemical and Engineering News*, Vol. 37, June 8, 1959, p. 62-67.

FLASH HEATING is simple. Finely divided absorbing materials such as particles of filaments are suspended in a transparent medium and exposed to a high-intensity high-speed flash. This causes the par-



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Flash Heating . . .

ticles to heat to high temperatures and cool almost instantaneously.

Since only a few milliseconds elapse between initiation and quenching, these thermal reactions do not undergo the usual side reactions that normally occur under longer exposure to high temperatures. Thus, information on the true reaction paths in high-temperature transformations should result from studies using this new technique.

To initiate thermal reactions by flash heating, we need:

• A transparent, insulating matrix, which can be solid, liquid, gas or vacuum.

• A small light-absorbing body suspended in this insulator. This can be a particle, a fiber, or a thin foil.

The light source is a spiral flash lamp similar to those used in some high-speed flash photography at Massachusetts Institute of Technology. The lamps are usually made of clear fused silica filled with a rare gas.

The lamps are powered by a large capacitor bank originally designed for commercial photography. Capacitances as high as 1296 microfarads charged to 4 kv. can be used; they give about a millionfold increase in intensity over ordinary continuous light sources. The absorption of the body need not be very high to produce heating effects, since the flash intensity is so great.

When a substance is actually dark in the visible range (carbon, manganese dioxide, copper oxide), it reacts violently within a matrix when exposed to the flash. Even materials normally thought to be transparent such as borosilicate glass or fused silica will also initiate these thermal reactions if the lamp intensity is high and the minimum dimension is small. Temperatures reached by this technique are on the order of 2000° C. (3600° F.) when the dark bodies are suspended in liquid and solid phases. They go as high as 5000° C. (9032° F.) when the matrix is a vacuum or a low pressure gas. Metals with melting points ranging from those of zinc through tungsten have been evaporated in a vacuum. They were in several small-dimension forms – powders, filaments, or foils. Filaments used have had accurately known diameters as low as 5 microns

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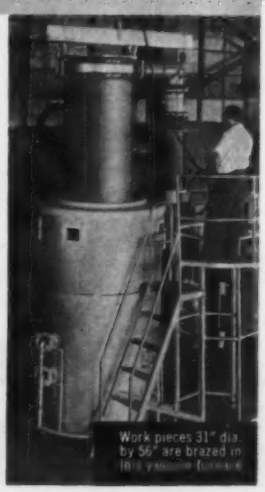

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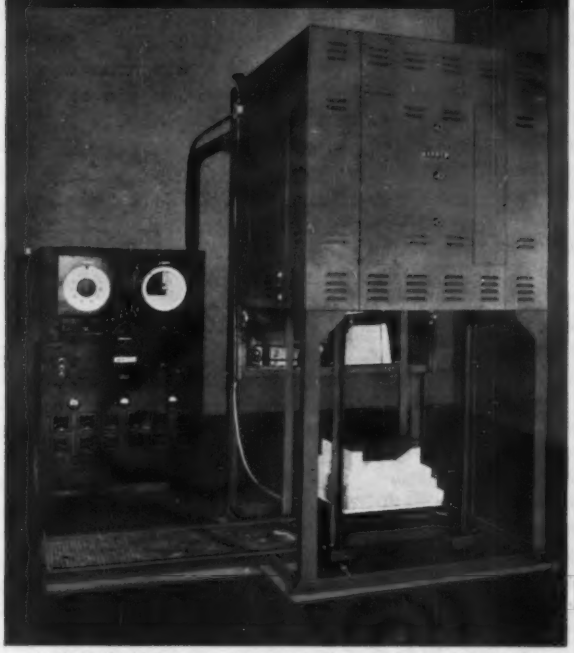

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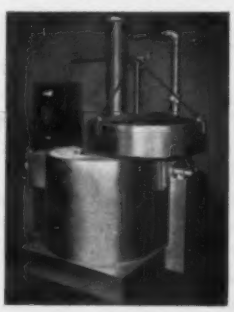

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Flash Heating . . .

while foils have had thicknesses as low as 15 microns. Powder particles were below 100 microns diameter. The author feels sure that these metals were boiled; heavy mirrors were deposited on the inside walls of the sealed containing tubes in all instances. An intense shock wave also apparently forms along with the vapor, because internal crazing frequently occurs on the borosilicate glass tubes. These small cracks never come through the glass but are very prevalent on the inside.

In developing this technique in the future, there is no reason to stop at the temperatures already reached, according to the author. Since the maximum temperatures depend directly on the intensity of the flash and inversely on its duration, temperatures can be increased by increasing the intensity or reducing the time of the flash. By using different circuitry, it should be possible to shorten the flash time by a factor of at least 100. Then temperatures much higher than those already achieved, and with shorter reaction times, seems easily possible.

C.R.W.

Corrosion of Zirconium

Digest of "The Corrosion of Zirconium in Hydrochloric Acid at Atmospheric Pressure", by W. E. Kuhn, *Corrosion*, Vol. 15, March 1959, p. 103t-113t.

ZIRCONIUM OBTAINS its resistance to corrosion from protective oxide and monohydride films. The manner in which these films are formed can alter the protective qualities of these films.

Tests with boiling 20% HCl of short duration (144 hr.) are influenced greatly by the original surface condition. Chemically and electrochemically polished surfaces display corrosion rates from approximately 1 to 2 mil per year, while mechanically polished surfaces corrode less than 0.2 mil per year.

Long-time exposure tests (2000 hr.) show a different trend. The mechanically polished specimens, which show very little corrosion up to 600 hr., suddenly start to corrode at a more or less constant rate. Conversely, electrolytically polished surfaces, which display a weight loss during the early period of testing, develop a protective hydride film and are resistant after the first 500 hr. Vacuum annealing for 3 hr. at 1150° C. (2100° F.) produced a surface which was remarkably resistant to corrosion over the entire 2000 hr. of exposure.

Superficial surface pits which exist on as-received material as a result of caustic pickling do not change on exposure to the boiling 20% hydrochloric acid solution. The as-received material displays the highest corrosion rate.

Specimens which were vacuum annealed in the 600 to 900° F. range displayed "breakaway" corrosion as described for the mechanically prepared surface above. The tendency was stronger with lower annealing temperatures. This effect is not observed for specimens annealed at 1000 and 1100° F. In either instance, the surface film is altered by the annealing temperature which produces a more protective film at higher temperature.

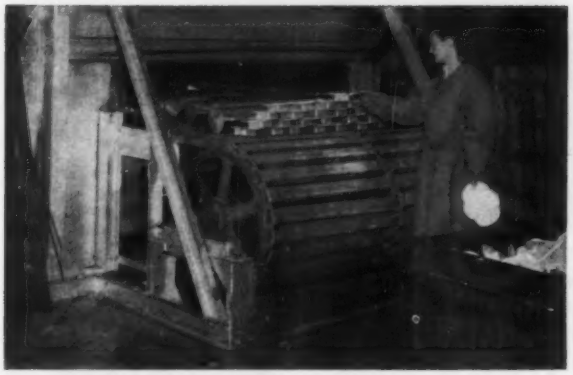
The investigation identified three characteristic modes of corrosion according to surface treatment:

1. **"Breakaway" Corrosion** – abraded and vacuum annealed metal surfaces. The initial attack is slow until the oxide film is destroyed and a sudden increase in corrosion is observed. Face-centered cubic zirconium monohydride with overlying films of monoclinic zirconium oxide are the corrosion products which define this corrosion mechanism.

2. **Porous Hydride Surface Films** – chemically polished surfaces. The chemical removal of surface films by an H_2O, HNO_3, HF solution employed in this work resulted in the formation of a porous, face-centered cubic zirconium hydride film. This film is nonprotective on subsequent exposure to hydrochloric acid.

3. **Dense, Coherent Hydride Surface Films** – electrolytically polished specimens. Specimens electrolytically polished in a saturated ammonium fluoride solution follow a logarithmic pattern of weight change. It is believed that the hydride film changes density during the first 720 hr. of exposure to hydrochloric acid, resulting in a hard, dense, protective film. After reaching a certain thickness, this film may be subject to cracking and separation from the metal and result in a sudden loss of weight.

F. H. BECK



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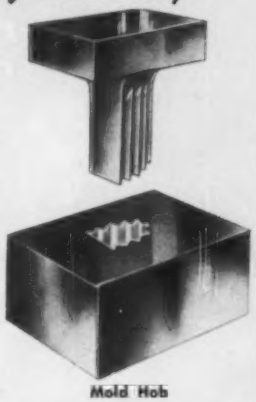

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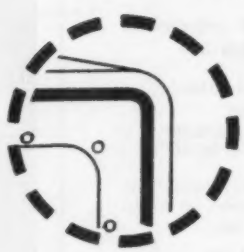

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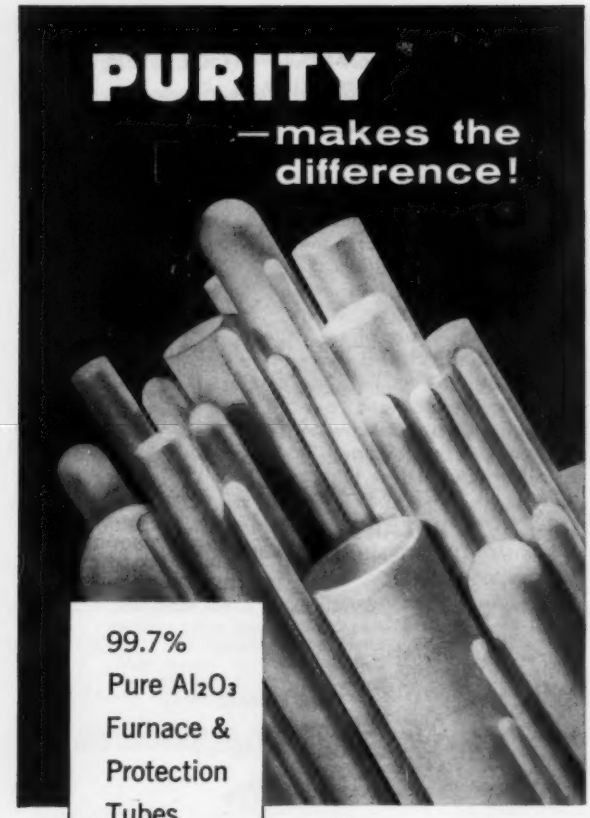

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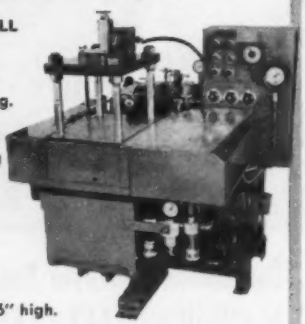

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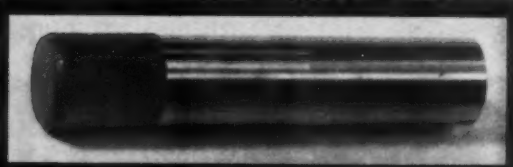

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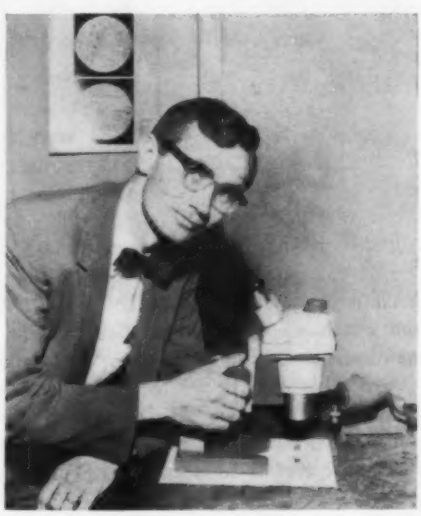
BEHIND THE BYLINES

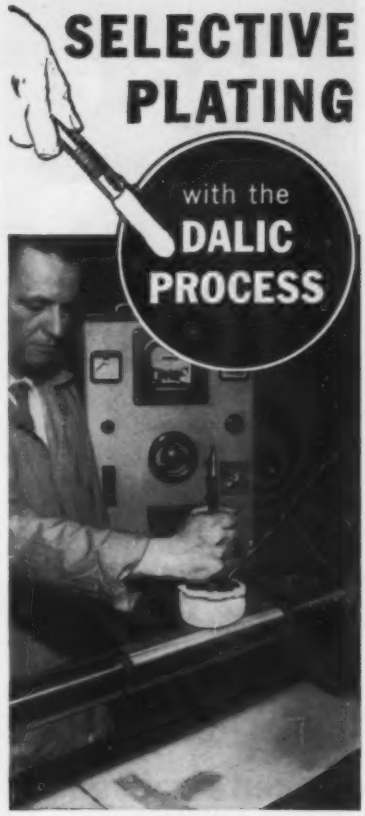
The photograph below shows W. H. Safranek of Battelle Memorial Institute examining one of several hundred zinc die cast panels electroplated and evaluated during the Battelle research program sponsored by the American Zinc Institute (and on which our lead article on new routes to better electroplating, p. 69, is based). Mr. Safranek, assistant chief of the electrochemical engineering division, is associated with various research projects aimed at developing finishes for protection against corrosion and finding new methods for producing metals; he has been at the research center since 1945.

A graduate of the University of Chicago, with a bachelor's degree in chemistry, he gained industrial experience working in electroplating at the Alemite Die Casting Co. and Apollo Metal Works.

His technical affiliations include A.S.T.M. (he's on the Committee B-8 on electrodeposited metals) and the American Electroplaters' Society (serving as a member of the editorial board).

Two experts in the large steam turbine generator department at General Electric in Schenectady, N. Y., D. L. Newhouse and B. M. Wundt, discuss a new test they devised for evaluating fracture toughness with small test specimens on p. 81. Since coming to G.E in Schenectady in 1945, Mr. Newhouse has worked in the materials and processes laboratory, a section of the large steam turbine generator department. In his present position as supervisor of forging development, he is concerned with development of rotor forging materials for turbines and generators, including evaluation and improvement of fracture toughness. At right he is examining a Charpy impact specimen.





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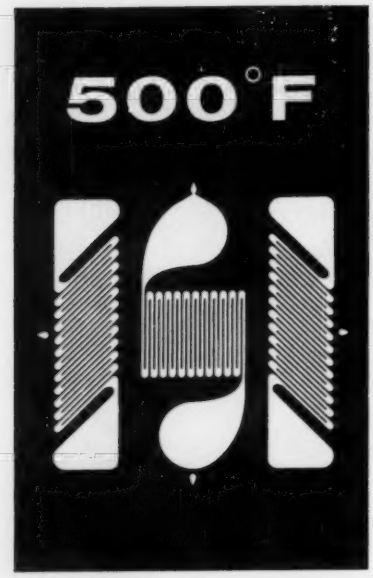

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Mr. Wundt had to go unphotographed, since at the time he was discussing this test procedure with authorities in Britain and western Europe. With G. E. since 1924, his work as structural engineer is with advanced problems in materials, stresses and vibration.

Mr. Newhouse's interests lie in the outdoors – sailing and canoeing in the summer, hiking and mountain climbing in the spring and fall, and snowshoeing in the winter. His wife and three young daughters are right there alongside him – except when it comes to snowshoeing. And they're working on that. Mr. Wundt's principal interests are his family, music and the voluminous world literature on application of engineering materials. He devotes most of his time to study of papers from many sources relative to his field.

The first article in our report on Frontiers of Welding Progress (p. 84) is by E. F. Gibbs, based on work done while the author was with Boeing Airplane Co. He joined the department of metallurgical research of Kaiser Aluminum & Chemical Corp. in Spokane last October and is now a research engineer in the welding research

branch. The bulk of his efforts at Boeing had to do with titanium welding research where he watched the metal develop in status from laboratory samples to volume production parts.

For really getting away from it all, he recommends mountaineering. For five months of the year he and others in a local climbing club can reach various ranges in four northwestern states and in southwestern Canada and can have "the chilly privilege of viewing a lot of spectacular scenery".

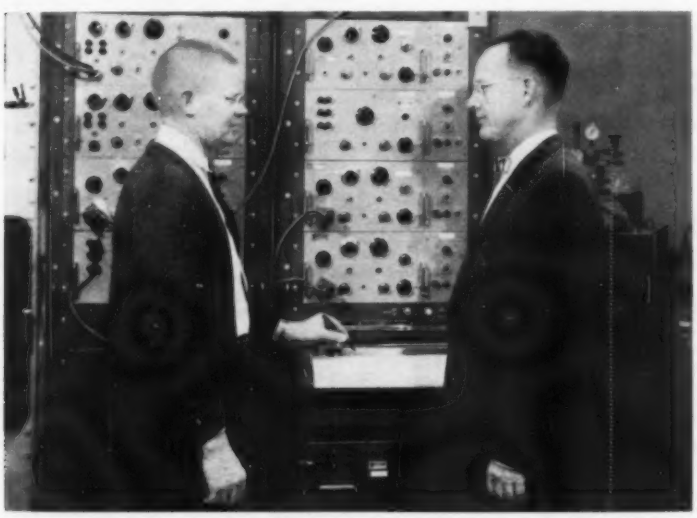
"Problems in Field Welding Chromium-Molybdenum Pipe" are discussed on p. 101 by R. L. Skaggs, materials engineer at Standard Oil Co. in Richmond, Calif. A graduate of the Missouri School of Mines in 1955 with a B.S. degree in metallurgical engineering, he worked for DuPont, then returned to his studies and earned his M.S. degree in metallurgy from Iowa State while holding a research assistantship with A.E.C. He joined Standard Oil at the Richmond refinery where his duties include refinery construction and maintenance problems and new materials evaluation.

A member of A.W.S. and A.S.M., he is currently the Golden Gate Chapter reporter. He has maintained a loyalty to swimming since college days and manages to "get wet" at least twice a week. His drier interests include knapsacking, welding (on a subapprentice level) and choir singing.

Thomas J. Moore's article on "Welding Electrodes for Welding Type 347 Stainless" is the result of a ten-year study of techniques for welding columbium-stabilized 18-8 stainless, conducted by the Subcommittee (of the Welding Research Council's High Alloys Committee) on the Welding of Stainless Steel of which Mr. Moore is secretary. A graduate in welding engineering of Ohio State University, he has been in the welding field since his graduation in 1953, first as a welding metallurgist with Babcock and Wilcox, then in the research department of Arcos Corp. in Philadelphia. He was appointed secretary of the Subcommittee in 1955.

His current favorite pastimes are playing with his seven-year-old son Kevin and "pulling weeds" at his recently acquired home in suburban Philadelphia.

"Instrumentation for Better Welds" (p. 111) is based on work carried out at North American Aviation's missile division and written by two of the division's engineers, Dexter J. Logan and Walter K. Moen (shown, right to left, below examining an eight-channel



recording of parameters). Mr. Logan, a seasoned welding engineer, has a background of 32 years in applications, research and development of welding processes and weldability of materials. His current assignment is as research engineer in the missile division.

A senior test engineer in the division since 1955, Mr. Moen is concerned with problems in simulation of high-temperature environments for missiles and components.

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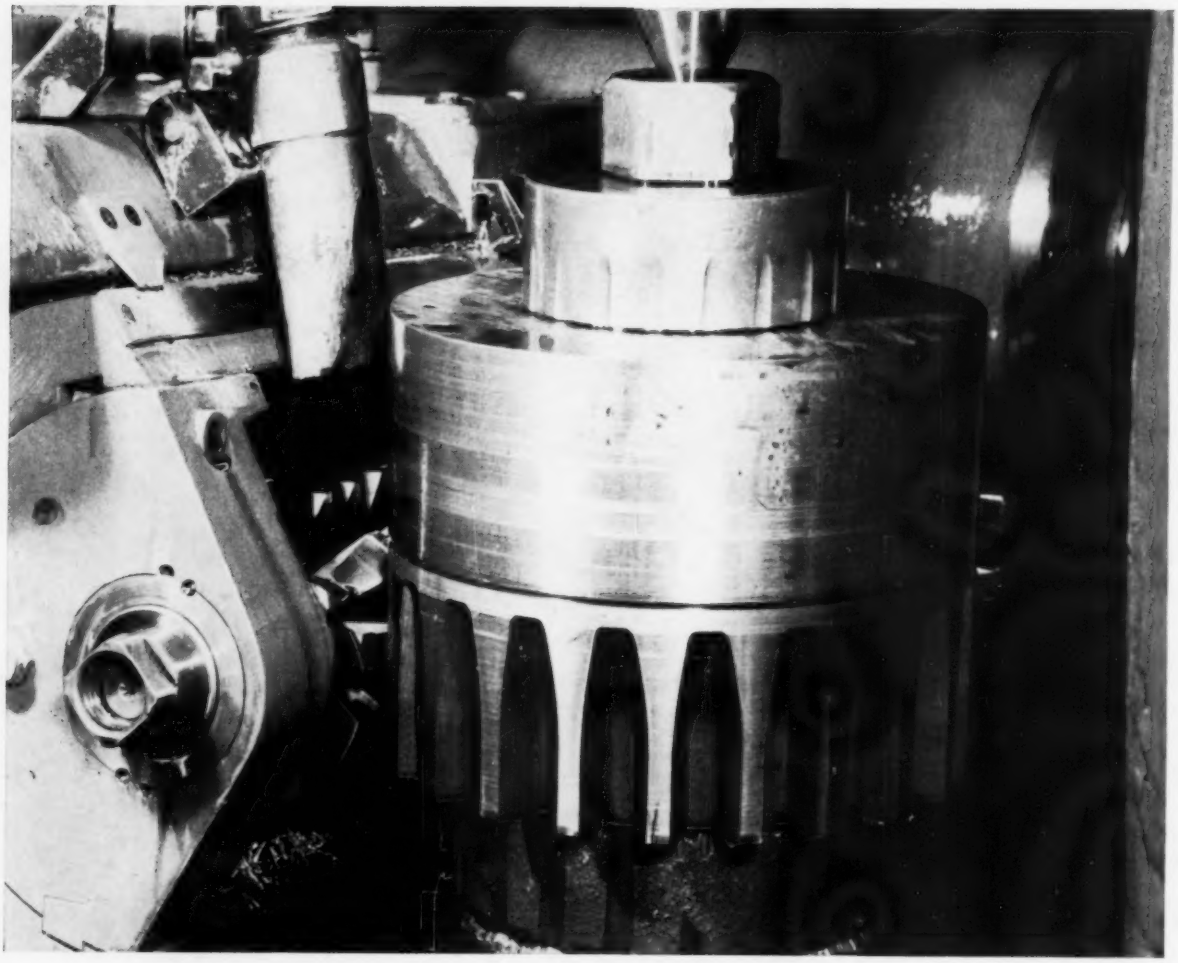

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